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The Artist's Handbook of Materials and Techniques

School of Archaeology.

RALPH MAYER

edited by Edwin Smith

THE ARTIST'S HANDBOOK OF MATERIALS AND TECHNIQUES

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Preface

This book has been prepared for the purpose of giving the artist a complete and up-to-date account of the materials and methods of his craft. It is based on my experience in the paint, varnish, and pigment industries, where I was engaged for a number of years in chemical research and in the actual manufacture of most of the basic materials used by painters; and on my experience as a lecturer and consultant to artists and as a painter. It is because the last is my chief interest that I have endeavoured to present the subjects from the viewpoint of the artist and arrange the material in a manner most useful to him.

The artist studies his materials and methods in order to gain the greatest possible control over his manipulations, so that he may bring out the best characteristics of his chosen technique and express or convey his intentions properly, and in order to insure the permanence of his results. Haphazard departure from approved methods will often involve a sacrifice in one of these directions, but those who have acquired a complete and intelligent grasp of underlying principles are usually able to vary the established procedures successfully, to suit their own individual requirements.

At present there are numerous materials and methods the use of which is well established by painters, but which are in an unstandardized state as regards scientifically correct knowledge or procedure. For instance, few modern investigators are in a position to pass judgment on the durability of traditional mural-painting methods under present-day conditions or to evaluate the merits of newly developed materials as definitely as such decisions may be made in other technical fields, where materials and methods have been more completely studied for their applications to modern requirements. There are still many gaps in our knowledge which well-directed investigation could fill in.

I have included a few notes on matters that are not ordinarily classified with materials and methods but that bear a similar practical relation to the artist's technique. I have also departed from conventional procedure in the rather frequent mention of trademarked names, commercial products, and names of their sellers. These widely available standardized products have in many instances taken the place of the ungraded materials of former times, and they have been referred to here solely from the viewpoint of the retail purchaser, as they are discussed among artists. It seems to me to be just as important to know where one may obtain a raw material and what to ask for as to know the Latin name of the tree from which it comes or how it is dug out of the ground. Because I have found from experience that a fairly large proportion of inquiries deal with obsolete or discredited materials and methods, I have mentioned some subjects which might ordinarily be omitted

from a work of this nature. On the other hand, certain subjects which are of greater concern to the theorist than to the active practitioner have been given less attention than they customarily receive. In reviewing the techniques of the past, I have confined my remarks to periods or schools rather than considered the specific methods and materials of individual masters.

The reader will find fewer instructions on the specific application of materials and methods to plastic and graphic arts than are customary in books on these subjects, because I believe that many such instructions are beyond the scope of a technical work, particularly since they are often open to divergent opinions or criticisms from a purely artistic viewpoint. In each case one must determine just where the discussion leaves the field of technology and enters the filed of aesthetics, and I have attempted to confine technical data to their general application to artists' techniques and to avoid either criticism or approval except on technological grounds.

In general, each of the various processes has been presented first in outline form, and then given step-by-step detailed treatment, the degree of completeness varying with the nature and importance of the process. Allusions to chemical and other scientific principles have been subordinated to a clear understanding of the subjects, and the reader has been referred to a separate chapter for the chemical aspects of the various topics. By dividing the material into separate chapters and by using cross-references and a complete index, repetition has been avoided as far as possible. Published accounts have been freely used, the source being mentioned in each instance; those who are interested in following up specialized subjects in greater detail will find selected lists of books on each topic in the bibliography. Many books have been published on certain of the individual subjects covered in this volume, and the titles I have selected should give a good basis for further study in these directions. The book lists were planned and arranged so that they might function as a guide to and a review of the field as well as a reference bibliography.

I owe my introduction to the study of painting materials to Dr. Maximilian Toch, under whose supervision much of my early training and disciplined experience was received. I am especially indebted to Mr. David Smith and to Mr. I. N. Steinberg for suggestions and assistance in the final preparation of my manuscript, and to Mr. Charles Locke and Mr. S. Levinson for similar services. The drawings are by Mr. Steinberg.

R.M.

Editor's Note

In editing this Handbook I have tried to extend its usefulness to English readers by replacing the author's helpful notes on American sources of unusual materials with the equivalent trade suppliers in this country. The text has been amended only where references to practice and manufacture which are common to both countries have been, quite naturally, identified with America, but which might lead to confusion if left in their original form. Materials, such as American woods and stones for carving, which are rarely likely to be imported have been deleted as unnecessarily tantalising; they have been supplanted wherever possible with British substitutes. References to the practice and experience of painters in the United States, however, as well as conclusions which may be fresh or controversial in this country, I have considered a valuable addition to our knowledge of American artists.

EDWIN SMITH

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Introductory Notes

In order to apply pigment to a surface or ground, the first requirement in most cases is that the ground be rough or coarse to some degree. The simplest method of applying colour, drawing with a lead pencil, a stick of charcoal, or a crayon, is based on this fact. The surface of uncoated paper is, microscopically, a web-like mass of long fibres; depending on the degree of coarseness of its finish and upon the hardness of the crayon or pencil, these fibres act as a file: they wear away the pigment particles and hold them within their interstices. Ordinary lead pencils are made of graphite mixed with variable amounts of clay according to the degree of hardness desired; the softest varieties contain little or no clay.

Graphite is a form of carbon that occurs in flat plates or flakes which have a slippery or greasy feel. The pressure of the drawing stroke not only forces these particles into the interstices of the paper, but creates a slight gloss or sheen by causing them to assume a flat, level position with their flat sides parallel to the surface, somewhat in the same way that wax is polished by causing it to assume a level, continuous surface.

Metallic lead has the same properties as graphite; when it is drawn across paper its particles are filed away and held in the mesh of fibres. Subsequent exposure to the impurities in the atmosphere will make these lead drawings blacker.

Thin rods of metallic lead were used as pencils by the ancients, and although graphite was known and applied to various uses much earlier, and crude graphite pencils began to be employed as early as the seventeenth century, the modern graphite or lead pencil in its present wood-encased form dates from about the beginning of the nineteenth century.

When metallic silver is drawn across paper that has been coated with a layer of white pigment, small dark particles of the metal are held in the porous or granular surface of the coating in the same way that the other materials are held by the fibres of uncoated paper.

Silver-point drawings, which were more popularly esteemed in the past than they are at present, are characterized by a certain delicacy of line. Unless immediately protected by fixative, the lines acquire a tarnish such as forms on all silver surfaces; this colour change, however, is usually desired, and the drawings are therefore left unfixed until it occurs. A number of commonly produced industrial coated papers will react with silver (as can be tested by a stroke with the edge of a shilling), but these are invariably made with little or no rag content and are of doubtful permanence. If special silver-point

paper is not available in the artists' supply shop, it can be made by coating pure, smooth water-colour or drawing paper with a thin layer of Chinese white, using a broad sable or camel-hair brush. The silver point itself may be a sharpened bit of silver wire held in an etching needle holder, or a thicker rod of silver ground to a point at one end and to a chisel edge at the other; both are procurable from a jeweller at small cost. Gold and platinum will make similar drawings of somewhat different colour. They do not change by tarnishing.

Painting

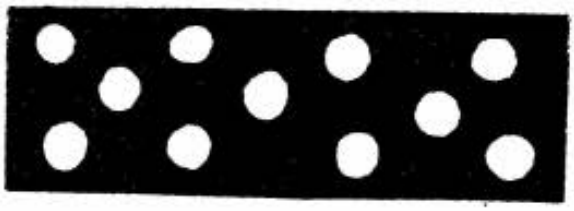
Surfaces. Liquid paints are filed off or taken from the brush in a similar way by the irregularities or tooth of the ground (paper, canvas, etc.) and also by absorption, which sometimes acts as an alternative or adjunct to coarseness or tooth. In very smooth grounds, absorbency of the surface acts as an alternative for coarseness, picking up the paint from the brush and causing it to drag in the desired manner. Both tooth and absorbency must be of the correct degree for the particular method and materials that are being used, and for the results that are desired, not only for reasons of manipulation but also to effect proper adhesion.

If one draws a loaded brush of oil colour across a clean sheet of glass, a highly unsatisfactory effect is produced; normal, direct painting is not possible, and adhesion is imperfect. If ground glass is used, a great improvement is immediately noticed; the tooth of this glass surface takes the colour much more satisfactorily. If the same paint be applied to a panel coated with a smooth, polished ground which has been coated with varnish in order to make it non-absorbent, exactly the same difficulty is encountered. If the ground is completely absorbent, the paint will be taken from the brush and drawn into the absorbent surface so rapidly that another obstacle to manipulation is presented: satisfactory painting is hampered by too much drag. If this ground is treated with a thin coat of size, so that its absorbency is of just the right degree, neither too much nor too little, the oil paint can be applied successfully. If pumice, a coarse, tooth-imparting, inert pigment, has been added to the ground, or if the ground has been scored or imprinted with a texture, oil paint is well taken from the brush, even if the ground is otherwise too non-absorbent to take it by absorption alone. Water colour and tempera paints require a full degree of absorbency for their proper functioning, but the surfaces of their grounds do not have to be particularly rough. The coarseness of very rough water-colour paper is for the purpose of imparting the desirable granular appearance or sparkle and has not much to do with brushing or adherence; smooth water-colour paper will hold the colour particles as well.

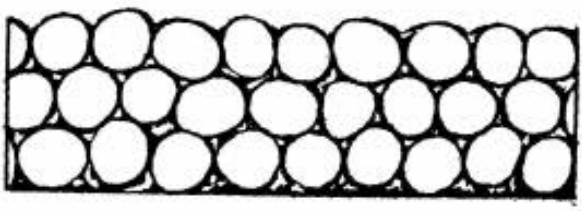
Occasionally painting on a smooth, non-absorbent surface—such as glass or a metal sheet—is required, but these processes are not in general use, and the resultant coating is seldom expected to last very long.

Binders in Paints. There are several types of binding action, and the

materials which depend upon one action should not be expected to produce either the visual effects or the physical properties of the others. A dried oil film encloses pigment particles in a continuous, glassy, solid substance. The film of a resinous varnish acts in the same way; it is even glassier, and is so impervious to atmospheric conditions that a thin layer of clear varnish will produce a durable film without any pigment.

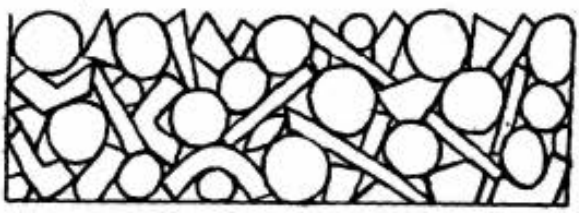


Tempera paint films are adequately strong and durable, but when dry the volume of binder in relation to the volume of pigment is less than that of oil paints. The pigment particles are surrounded by the binder, but unlike the condition in the glossy oil film there is little or no excess medium, the surface has a mat or semi-mat finish, and the layer is porous.



Simple solutions of gum, glue, casein, etc., are more powerful adhesives than oils and resins; they will bind the pigment particles into a mass and attach them to the ground, but they do not form very durable films by themselves. When such paints are thinned to a brushing consistency, the pigments will be well bound but not locked in by a continuous level film, and so their surfaces will not be glossy.

Binders such as the lime in fresco painting fall into another class. They act merely as cementing materials; they hold the particles of pigment or sand to each other but give no protection against outside influences. The surface is porous and any resistance against external attacks it may have is due to its own inert nature and that of the pigments.



Fixatives, such as are employed to bind the pigment of pastel and crayon pictures, are very weak solutions. They are expected to be absorbed by the surface and they supply only enough superficial binding action to reduce the fragility of the picture so that it can be handled with somewhat more freedom.

Balanced Formulas. In the formulation of a liquid paint or the establishment of a painting technique, there is a fundamental consideration which may be called the 'balance of solubility'. A certain balance or relation must be maintained between the resistance of the coating, the solvent action of subsequent brush strokes, and the solvent or dispersing power of the liquid used. For instance, the gum binder of water colour is completely soluble in water, yet the dry paint layer is sufficiently resistant so that it is possible to apply subsequent brush strokes without disturbing it; on the other hand, the paint is not so resistant that it cannot be softened or run into when the painter so desires. The wet paint itself may be instantly diluted or thinned with its normal solvent, water. A poorly made water-colour paint, or one which could be called unbalanced in this respect, might be picked up and completely removed at the touch of a wet brush or it might dry too resistant to water to be worked into when desired. The best water-colour paints are perfectly balanced and adjusted to the normal water-colour techniques.

In the oil-painting technique the turpentine or mineral spirit has sufficient solvent action to function as a thinner for the wet paint and also to dissolve the freshly applied or recently dried coating if scrubbed into it, yet a freshly dried surface will not be picked up, spread, or dissolved away if overpainted in the correct manner. Oil paint can be freely mixed and blended if desired, it can be made to set quickly enough to withstand the solvent action of further strokes without running in with them, or it can be made to remain plastic long enough for most normal working procedures. If a glaze or overpainting contained acetone or some other powerful solvent the underpainting might be picked up or it might spread. One of the principal disadvantages of the modern lacquers and synthetic resins in painting is that as a class they are insoluble in all but the most powerfully solvent and highly volatile liquids, thus creating obstacles to controlled manipulations.

Some techniques are less flexible and their manipulations do not involve the same degree of solubility of recently applied colour—for example, fresco, in which the brush strokes are not altered by overpainting and where such effects as gradations of colour, tone, or shade are normally achieved by hatching or the application of separate strokes. Other techniques demand various degrees of solubility in their materials, and the standards for paint formulas and ingredients, brushes, grounds, and manipulations used in each vary widely according to its requirements.

Home-made Materials

The artist's home manufacture of painting materials has been criticized and defended on various grounds by twentieth-century commentators. The modern painter who makes or refines his own materials does so because the particular quality or variety he desires cannot be purchased, because his process demands certain operations which must be performed immediately before use, for reasons of economy, or because he enjoys it as an enlightening avocation. Well-directed experience in this activity is obviously one

of the most valuable means of acquiring knowledge that leads to control of materials.

A chronological study of the old manuscript treatises which were written for painters rather than for those primarily concerned with producing materials in commercial quantities shows that one by one, with the advance of time, recipes for pigments and mediums are omitted or accompanied by remarks to the effect that their preparation is not worth the trouble and risk of failure, since they can be purchased ready-made.

The development of our modern industrial system on an economy of mass production makes it quite understandable why it is impossible for the producer of a raw material which is sold daily in waggon loads to turn out with scrupulous care the insignificantly few barrels of his product which the artists of the world consume annually. One of the contributory causes of the decline of standards for materials at the same time that advances in technology and knowledge made it possible to improve quality was the development of the paint and colour industry from one which produced materials largely used for decorative purposes to one whose products are primarily used for large-scale industrial or protective purposes. Pigments, oils, and other products, highly satisfactory for industrial purposes but of quality inferior to that demanded for artists' use, are made in enormous quantities. The superlative grades are produced on a much smaller scale and are not so widely available.

The painter, sculptor, or graphic artist who is well acquainted with the properties of his materials is often able to improvise quite acceptable materials when for various reasons his normal supplies are unobtainable or when he is confronted by the numerous minor emergencies which arise in the progress of his work. However, the writer or instructor who is intent upon conveying the most correct and approved ways of achieving good results does not ordinarily concern himself with possible remoteness from sources of supply and similar considerations. Hiler[37] mentions some interesting emergency methods for the preparation of materials when the proper ingredients and ready-made supplies are not to be had; other books, including this one, also note such procedures occasionally. It must be understood that no one recommends these expedients as regular procedure, and that the artist should have sufficient experience to judge for himself whether makeshift materials are suitable for his permanent work or whether their use should be confined to notes and sketches. The drawbacks to the use of common oils, decorators' pigments, home-made curd paints, etc., are all well known to the careful student of materials.

Quality in Ready-made Artists' Supplies

While the use of students' grade materials may be justified on economic grounds for the beginner in his very early stage, it is a question whether this practice is not carried too far. If, as soon as the student has completed his very early attempts and has begun to think and act for himself, he continues his

training with the best professional materials he can possibly afford, he should be on the road to a much better control of his materials and methods than if he is introduced to the sort of materials that 'make all the difference in the world' after he has already established his technique, or the background for his future technique, on a basis of inferior materials. A great number of our younger professional artists, whose works are well circulated, continue the use of inferior materials. There is such a small demand for really first-class goods that some of the largest supply stores are often lacking in the better grades of canvas, paper, colours, and brushes.

An apprentice in any of the manual or mechanical trades soon learns all about the quality of his tools, and acquires high-grade professional ones early in his career. An ordinary house painter engaged in the most commonplace sort of work would scorn to use a brush comparable in quality and condition to some of the artists' brushes with which paintings are done. Artists should know that the use of cheap materials not only affects the quality of their work, but is often not economical; a pure, strong colour will go further than a weakened one, and a good brush will outlast several poor ones. The one way a student can learn to judge such materials, after he has been taught all that can be imparted to him regarding their selection, requirements, characteristics, etc., is to be allowed to work with them. Possibly some of the lack of interest in this subject is due to an overreliance on the truism that no amount of opulence in materials will make a good painter, and that a good painter can turn out surprisingly good things under adverse conditions.

The production of prepared artists' colours in some European countries is sometimes handicapped by the tendency of the producers to employ pigments of domestic origin almost exclusively. If a manufacturer honestly wishes to make high-grade paints, he will select the materials solely on their merits, regardless of their points of origin. Some natural earths such as Raw and Burnt Siennas (Italy), Yellow Ochre (France and Italy) occur in their best form only in certain limited districts abroad and there are a few colours—e.g. Carbon Black (America), Arsenical Cobalt Violet (France)—which are used solely by artists, in such small quantities that it would be economically impracticable to produce them here.

There is no longer so much cause to quarrel with the manufacturers of good artists' materials on the score of their prices; it is reasonable to agree that considerable expense is involved in the care and technical skill required to select the highest-grade materials and to compound them properly. Furthermore, the maintenance of stocks and the distribution of the finished products will result in a higher percentage of cost in such products than in those which are consumed in greater quantities. In fact, most of the higher-grade materials which go into artists' paints are produced in quantities which are significant in comparison with quantities of similar products made for mass production.

However, the artists' colour trade is like every other in that there is always the possibility that unscrupulous firms will trade on the reputation of fine materials and substitute inferior grades under the same name; the main-

tenance of high quality is entirely up to the conscience of the maker, because the majority of manufacturers have or can easily obtain the technical skill and knowledge to produce as good material as they please. There are few technical secrets in modern industry.

Ordinary house paints and varnishes are of three grades: first, the best possible products that can be turned out with reasonable allowance for the availability of supplies and restrictions of distribution; second, the best possible material that can be made within a limited or competitive price range; and third, the cheapest sort of rubbish that looks and smells like paint. If a responsible manufacturer makes second-grade products, he will be careful to indicate the fact, but there are firms, particularly jobbers and sales organizations that do not maintain their own factories, which sell second- and even third-grade paint advertised to compete with first-class products. It is possible that something of the same sort may also occur in the artists' supply trade. However, conditions at present are much improved, and the standards of quality, even among the cheaper grades, are higher than they were in the recent past. A few years ago I had occasion to examine three tubes of artists' white, of a brand no longer on the market, which were sold at a low price but with no intimation that they were of students' grade or otherwise inferior to the best, and found that the three—zinc white, flake white, and Cremnitz white—apparently came out of the same tub. They were identical mixtures of lithopone, a little zinc oxide, and nearly 20% barytes ground in an oil which contained materials to give the colours an acceptable buttery consistency. At the present time, selection of prepared artists' materials rests upon the experience and judgment of the user, substantiated by simple tests which he is able to make, such as exposure to light and a rough strength test, as outlined in this book. Despite various attempts in the past, no satisfactory practical standards have been established for the control of artists' materials. Such a project would have to be guided by modern technicians whose judgment would be largely based on the artists' viewpoint with reasonable allowances for the manufacturers' problems. At the present writing a move in this direction is being made in America under the auspices of the National Bureau of Standards (see page 444).

Historical Notes

The earliest works of art of which we have definite knowledge are prehistoric, that is, they were produced during periods antedating the times for which we possess contemporary records and of which our knowledge is definite or accurate. The word prehistoric is here used in a narrow sense, relating directly to art, and does not necessarily imply that we have no definite, accurate knowledge of other aspects of the cultures that produced these works of art. Of some countries—for example, ancient Greece—we have a good knowledge of the civilization, the literature, architecture, ceramics, etc., but only a vague idea of the materials and methods of mural and easel painting.

Our information concerning the methods and materials of these periods is derived from relics, archaeological discoveries, and from the writings of the earliest historians. Considerable time separated these writers from the periods in question, and although much of value has been learned from them, their writings also contain much that is legendary, vague, and inaccurate; some processes are described correctly in accordance with methods which have survived or developed along similar lines down to the present day, while other statements are the weirdest sorts of fantasy. Sometimes, important archaeological discoveries such as those of Troy and Knossos have substantiated historical or epic legends which previously had been considered unfounded on actual fact. The most valuable aid in reconstructing an old painting method and arriving at a definite conclusion is an intimate knowledge of the behaviours and properties of painting materials and the results which may be obtained by various manipulations, gained through first-hand painting experience and experiment.

All the raw materials used in art techniques, with the exception of some few new products or improved grades introduced during the recent age of industrial and scientific development, are of far greater antiquity than is popularly supposed. The materials which were considered as improvements during the introduction of various techniques from the thirteenth century on were well known to the ancients. The principal literary sources which mention painting materials and methods of the classical period, and upon which investigators have based many deductions, are Vitruvius and Pliny, with lesser accounts by Theophrastus and Dioscorides.

Modern investigators have exhaustively studied all the known sources and references to painting materials of the past, not only the more complete accounts but also the isolated references and clues in non-technical writings.

The development of art in general proceeded along distinctly separate channels in the various countries, but always was governed by the culture and type of civilization and the available supply of raw materials, choice or selection of which was strongly influenced by climatic conditions and the uses to which the works of art were put.

Egypt. The preservation of Egyptian relics because of the perfectly dry atmosphere of the country and the precautions taken to insure the safety of mortuary deposits is well known, and students of Egyptian civilization have given us a very thorough understanding of the painting methods employed. The history of these methods constitutes a remarkable record of the survival of a technique, which remained essentially unchanged for a period of about 3000 years. Although the art and culture of the Egyptian civilization underwent changes during this period, these changes occurred within fairly limited bounds, and the following two processes served from the date of the earliest existing specimens (about 4700 B.C.) down to the time of the Ptolemies:

1. Mud-plaster walls were decorated with a simple water-colour paint.
2. Designs were engraved or cut in stone walls and gone over with water-colour washes.

Minor, isolated examples of other variations have also been found.

The precise nature of the binder in the Egyptian water colour is uncertain; gum, size, or some similar material was used, or perhaps all of them, and the colours were applied with crude fibre brushes. It is usually assumed that gum arabic was in greatest use. These water-colour paintings on mud-plaster walls which have survived so well in the dry climate and sealed tombs of Egypt may be entirely destroyed by passing a damp sponge across the surface. The work of the later periods was technically more refined, better and finer brushes and pigments were used, but the process remained the same. Lime-plaster was not used prior to the Roman influence.

Greece. The Minoan and other pre-Hellenic Greek civilizations developed a fresco process virtually identical with the *buon fresco* of Renaissance Italy; it is described in the chapter on *Mural Painting*. The two principal Greek methods of painting easel pictures—according to Pliny, Vitruvius, and other writers—were encaustic and a mysteriously vague second process variously supposed by modern writers to have been oil, egg tempera, or dissolved or emulsified wax. No conclusive evidence has so far been established on this point, but the methods, materials, and implements of encaustic painting are well known. A large amount of the tradition and legend concerning the highly praised early Greek painters is probably apocryphal and of small value in the study of their techniques. No authentic Greek paintings of the classical period are known to exist; the Pompeian relics have in the past been considered typical of them, but more modern students find that they throw little light on the subject. The Greeks seem to have had a complete unconcern for any sort of recorded data and, unlike the Egyptians, no regard for the preservation of works of art beyond their immediate functions; few statements about their mural or easel painting methods or materials are entirely free from conjecture. The principal source of our knowledge of the artistic as distinguished from the technical nature of Greek pictorial art is the study of the decorated pottery and a few other relics which happen to have survived because of their durability. The Roman materials are somewhat better known to us through contemporary records.

Medieval Europe. The period which follows, i.e., the early Christian or medieval era, supplies us with a somewhat larger number of surviving examples of painting, and also with written accounts of a more definite character in all countries. These include manuscripts written by contemporary craftsmen and specialists for the purpose of disseminating their knowledge, records of expenditures for materials, and letters of painters.

Much of our knowledge and evidence concerning techniques of the past is based on the study and careful interpretation of the early manuscripts. A long list of such documents could be made; some of them are well known to students, and others have received little attention. Most of them have been translated into English and critically interpreted by experts, and those interested in referring to them may find them among the books listed in the bibliography for this section. A good bibliography of early manuscripts and books is listed by Laurie,[23] although it is to be noted that some

of the translations mentioned in it have been superseded by more modern ones.

The painting methods and materials of the Italian Renaissance are well documented and the technology of its various schools and individuals fairly well established: fresco, egg tempera, and oils. Those of the Northern painters are somewhat less well established; their early records are less often in as complete or treatise-like form; the members of their guilds were less restricted by a single, established mode of procedure, and they seem to have done more toward the development of new materials and processes.

Tempera Painting. From crude beginnings in Byzantine and early Christian art and, as some early writers suggest, but without definite proof, from the ancient Greeks, a traditional tempera process came into general use throughout Italy. The pure egg-yolk technique was described by Cennino Cennini,[7] in a treatise on painting as practised at least as early as the fourteenth century: it was well established in his day, and his knowledge and training in it came to him in direct line from the earliest recorded Italian painters. Tempera was the principal medium used for easel painting in Europe until the development of artistic oil painting.

As Eastlake[14] expresses it, the early Italian painters, though taking great care to produce durable works, made no attempt to lessen executive difficulties, tending rather to overcome such difficulties by superior skill. The Flemish and other Northern painters departed from the early Italian methods, using new materials, aiming at ease of manipulation, and producing works technically excellent to a degree impossible to duplicate by strict adherence to the egg technique of Cennini. These methods and materials are supposed to have been initiated about the year 1400 in Flanders and thereafter introduced into Italy. The period from the beginning of the fifteenth century to about the middle of the sixteenth century produced tempera paintings of a high degree of technical excellence, which serve as models for the tempera techniques of today.

At the same time (beginning about 1400) new materials began to be discovered or perfected. A commercial renaissance began, a result of which was the wide distribution and availability of raw materials. Traders brought supplies from the Orient, and the manufacture of finished goods on a larger scale brought improved qualities and uniformity to materials in common use.

Linseed oil had been known and used for ordinary decorative and protective coatings from the earliest recorded periods of European history, but it was a crude, mucilaginous product unlike the well-made material we know now as raw linseed oil; however, thinners such as turpentine were virtually unknown. Processes for the purification of linseed oil in the modern sense began to be published about the year 1400.

Distillation was known to writers of the third century A.D., but it was not practised commercially until the fifteenth, at which time its products, alcohol and other volatile solvents for varnishes and paints, began to be widely available.

The aim and taste of the artist and his public should be taken into con-

sideration when a study of these changes in techniques is made. Vasari and other writers who lived in a day when tempera was becoming obsolete, and when the novel effects produced by oils were widely acclaimed, were often prone to condemn the tempera technique from the viewpoint of the tastes, fashions, and styles of their day. Tempera painting was condemned by them as inferior to oil because of the very qualities which make it appeal to its present-day users.

During the sixteenth and seventeenth centuries, some tempera paintings were done on canvas, which had been introduced with the oil painting technique, by that time in full swing. Tempera as a universally used medium in a high state of technical development may be considered to have become obsolete by the end of the sixteenth century.

In following out any recipes or instructions of former times, even up to nineteenth-century methods, it is important to remember that the quality, character, and nomenclature of many raw materials have undergone changes, and to be familiar with the artistic or pictorial aims of the period for which the methods were intended.

The statement, made in accordance with general opinion, that tempera painting became obsolete more than three hundred years prior to its present revival, is true only so far as its wide general usage is concerned. Examples and records of isolated works done with the older materials can be cited for almost every age, but these individual experiments had small influence either on the general practice among painters of the time or on the major part of the painter's own works. The present revival of tempera owes its extent to the adaptation of the technique to the requirements of modern taste, since it makes possible effects particularly well suited to certain modern artistic aims which did not exist in the recent past. In the early part of the present century it seems to have received its greatest impetus in Germany, although isolated groups of English and American painters also pioneered in its use.

Some partial use of tempera by American painters of the early nineteenth century is recorded. Sully[16] recommended that colours be ground in skim milk (crude casein). A ground made from skim milk and white lead was one of his favourites, and he also mentioned the use of colours ground in skim milk for underpaintings, carrying this work as far toward completion as possible, then finishing with transparent oil and varnish glazes. An emulsion of flour paste and Venice turpentine is also mentioned.

Oil Painting. All references to the so-called discovery of oil painting by one man or one school of painters in an attempt to find a method that would revolutionize art have long been held to be fallacious. The drying properties of linseed, poppy, walnut, and hempseed oil were known to some of the earliest writers, and instances of their application to paint are found quite frequently in early records and in accounts of expenditures for materials. The use of such paint, however, was confined to commonplace or simple decorative purposes: no traditional methods for work of purely artistic pretensions were established until later times. From an examination of the old expense

records, oil paint is seen to have been widely used in England for decorative purposes at least as early as the thirteenth century. Eastlake[14] collected many of these records.

When the demand and preference arose for a new type of easel painting that could not be produced by using the pure egg-yolk technique, or any other method then in use, the new materials and improved grades of older materials were at hand and were applied to produce these effects. Changes or innovations in techniques are more often attributable to changes in times and circumstances than to deliberate individual creative departures.

The fifteenth- and sixteenth-century paintings innovated by the Flemish artists soon after the year 1400 and referred to by Vasari and other older writers as oil paintings were, for the most part, precisely the sort of works we call tempera paintings today when referring to tempera in the highest stage of its development, and some were produced by employing alternate coats of tempera and oily or resinous mediums as in the accepted tempera variations.

The simple direct process for easel pictures which is known as oil painting did not come into universal use until the seventeenth century, although it appears occasionally during the sixteenth. Various individual masters of the sixteenth and seventeenth centuries have been cited as being the first to show the complete adoption of this procedure, but it is hardly reasonable to believe that such definite statements are accurate when applied to a technique which has had a long and gradual development. However, during the seventeenth century, the practice of painting pictures throughout with oils and varnishes increased and finally became common. At first the gesso grounds of tempera were used, and, according to most modern investigators, resinous varnishes such as are classified as glaze mediums in this book, were largely mixed with and used in alternate layers with oil paints. After 1700, oil grounds and straight oil colours were in almost universal use. Some painters, believing in the superior luminosity of gesso as a ground for oils, have continued to use it down to the present day. Although one of the advantages of the oil technique is that it can be used on oil-primed canvases of light weight, the more cumbersome wood panels were never entirely discarded; some artists have always preferred their smooth surfaces or superior rigidity.

The early linseed oil referred to in the preceding remarks on tempera was pressed from flaxseed and purified by heating and sometimes by the action of sunlight. The two principal improvements of the fifteenth century are generally considered to have been the adoption of methods of purification by mixing the crude oil with water, which removes the impurities and produces a superior raw oil, and the wider availability and use of volatile thinners.

Drying oils of the early type had been used from very early times as occasional minor additions to painting techniques and for protective and simple decorative purposes. They are mentioned by Galen, a medical writer of the second century, and on through the medieval recipe books and treatises as well as in records and accounts of various decorative projects, but at none of these times were there established any standard methods of oil painting as

applied to purely artistic work. Stand oil has a long history and it is believed by most investigators that it was widely used by artists of the Dutch school during the seventeenth century.

Studies of the materials and methods used by the individual painters of various periods may be found in the works of Eastlake,[14] Laurie,[19 23 24 34] Doerner,[38] and others. The first-mentioned contains the most complete references to early writings; the more modern writers combine the data accumulated by earlier historians with material developed by themselves and others through studies along more progressive lines.

Some of the successful and durable effects produced by the great painters of the early days of oil painting have been attributed to the use of resins mixed into the oil paint. It is my opinion, both from experience and from the results of other investigations on these materials, that when resins or resin varnishes were so used, the most successful examples probably employed the simple solution or liquid balsam type rather than the type of resin that requires cooking in oil with driers and other chemicals. Most of the early recipes for the use of resins that will not dissolve without being cooked in oil will generally produce solutions which are inferior in permanence to the modern cooked oil and resin varnishes, none of which is considered permanent enough for use in artistic painting.

The Chinese were well acquainted with several kinds of drying oils for many centuries and employed them for various technical purposes, but their pictorial art was confined to ink and water-colour tints on paper. A drying oil was used as a medium for the vermilion seal which was impressed by the artist on each painting. Their fundamental conceptions of pictorial art were exactly served by the materials they used, and although in later days they may have absorbed Western influences and ideas, Western materials have always been rejected by them.

Later Periods. During the eighteenth century, and more completely during the nineteenth, the knowledge and intelligent study of the methods and materials of painting fell into a sort of dark age, from which our contemporary painters have by no means entirely emerged. Good craftsmanship and a thorough knowledge of materials and methods continued to be the concern of some painters, but they were exceptions to the general trend.

The beginnings of the era of great industrial and scientific development released artists from a number of details of labour indirectly essential to their work, so that they began to concentrate their efforts entirely on the plan, design, and execution of the work, leaving the preparation of materials and other auxiliary work to specialists, upon whom they eventually became thoroughly dependent. The first effect of this development on the practice of painting technique was to end the necessity of the artist's learning thoroughly the laborious hand or small-scale methods of manufacturing his materials. Instead of giving the art student some degree of organized training in the principles underlying the properties and uses of materials as a substitute for the practical experience stressed in former times, the entire subject was eventually ignored.

Traditions relative to handling painting materials survived for some time, but inasmuch as these were passed on in terms of effect or 'how', without regard for cause or 'why', they soon degenerated to a set of fixed rules, and by the end of the nineteenth century we find few painters equipped with an intelligent understanding of the craft.

It was a short step from this attitude to the conviction that too great concern with the fundamentals of technically correct practice would interfere with or hamper the free expression of artistic intentions. The bulk of the work produced by men of this belief has become generally, in all artistic circles, the least valued from a technical viewpoint.

One of the first results of this decadence was the general acceptance of the theory that the great masters of the past had mysteriously and closely guarded secrets through which they obtained their effects and the permanence of their works. Many artists of the eighteenth and early nineteenth centuries seriously attempted to improve their craftsmanship by continual independent study and experiment, and they worked on their mediums until they attained fine control and the exact expression of their artistic intentions but failed to secure permanent results; a great many of these pictures have deteriorated within a comparatively short time. This can be attributed to misguided effort in the search for the 'secrets of the old masters'.

Eastlake[14] suggests that the word secrets as used in the medieval recipe books was not employed in the sense that such information was always jealously withheld. There is much evidence that such information was as freely circulated among members of the craft as it is today, and that it was not until more recent times, when this resurrected knowledge not possessed by the majority had a direct commercial or competitive value, that it was more jealously guarded.

Almost every writer on the technology of painting points out the fallacy of the belief of some painters of the recent past that any close attention to the technical details of their craft would interfere with the free expression of their intentions, and that by concerning themselves as little as possible with such matters their creative efforts are left untrammelled. In one way or another, students of technique have shown that the work of the pre-eminent masters of the past was produced under conditions of the most highly developed craftsmanship; that the artists of the Renaissance made little distinction, if any, between their craftsmanship and their artistic intentions, and showed little concern for aesthetics entirely divorced from craftsmanship; that a first-hand knowledge of sound technique is of enormous assistance to the painter in enabling him to express his intentions with accuracy; and that the knowledge that he has utilized the best possible means to attain his ends and to insure permanency brings an increase of confidence.

I have no doubt that this attitude during the latter part of the nineteenth century had an effect on the development of art forms; such a point of view was bound to contribute certain elements to the nature of the art produced, and many of the more dominant personalities who subscribed to it were led into methods of applying paint which, though unsound from the viewpoint

of earlier, more accomplished painters, produced certain novel effects that could be used to support new artistic or aesthetic aims. However, much of the work produced under these circumstances is considered to be of little merit by most present-day schools of painting.

The electric light removed another restriction that tended to keep oil painting within the bounds of correct and safe practice. Mention is made in this and other books of the ill effects on permanence of excessively thick, pasty layers of oil paint sometimes studded by still heavier areas of almost modelled impasto. Such paintings would have been impossible in the era preceding our present controlled illumination; only by manipulation of individual lighting can they be made to stand out with all the dash and sparkle intended by the painter. When one views a collection of historical portraits in ordinary general illumination, the older ones done in an age of lamps or gaslight, whatever their aesthetic value as pictures, are clearly and successfully visible, whereas the type painted in spectacular impasto strokes will display annoying blobs of colour and glare. Not until scientifically adjusted lighting is switched on do these more modern works take their place as paintings worthy of comparison with the others. This is also true of another type of work where glossy retouch varnish has been used for a final touching up in spots, to bring out or secure certain proper tonal relationships, thus obtaining colour values by manipulation of refraction, absorption, and reflection of light from smooth and rough surfaces, instead of by the use of pigment. Such effects are never very permanent. Close examination of the type of painting which piles great blobs of colour over thick pasty undercoats reveals thirty-year-old works so badly cracked that they seem headed for oblivion. No criticism of the artistic value of these works is intended; but their effects, whether one considers them admirable or deplorable, could have been achieved by sounder methods.

In America there were scarcely any new contributions or developments in the field of painting materials and methods, for in the beginning the tradition was entirely English and thereafter followed the techniques of various European schools very closely.

That tempera and other departures from the standard direct oil technique were known to some early American painters is evident; researches among the voluminous biographies, letters, and records of these painters of the early nineteenth century would undoubtedly disclose many interesting accounts of their painting materials and methods, but they have been ignored because of the low esteem in which the mass of early nineteenth-century painters have been held, even though some of them show a degree of craftsmanship far surpassing the usual level of their time. Dipping into these records here and there, we find observations on the relative merits of solid painting and the use of glazes; we see portraits of the 1840's in which glaze effects were successfully used both in backgrounds and in faces. This apparently became something of a lost art in the second half of the century, for the works of that period reveal much less success in the attainment of these effects. Some of the earlier American uses of tempera and oil-resin glazes are mentioned on page 27.

In the past, the discovery, or rather the widespread application, of new and improved raw materials and technical methods, almost always coincided with the introduction of new art forms. This statement is not meant to imply that such material innovations were the deciding factor in the genesis of new art forms, but that such materials and methods are ultimately put to the uses for which they are inherently best suited. This occurs in the present day, when new developments not only in artists' materials but in all other fields of activity are often first applied as imitations of older forms, and are not utilized to their fullest extent until a new demand or a new conception of their value arises.

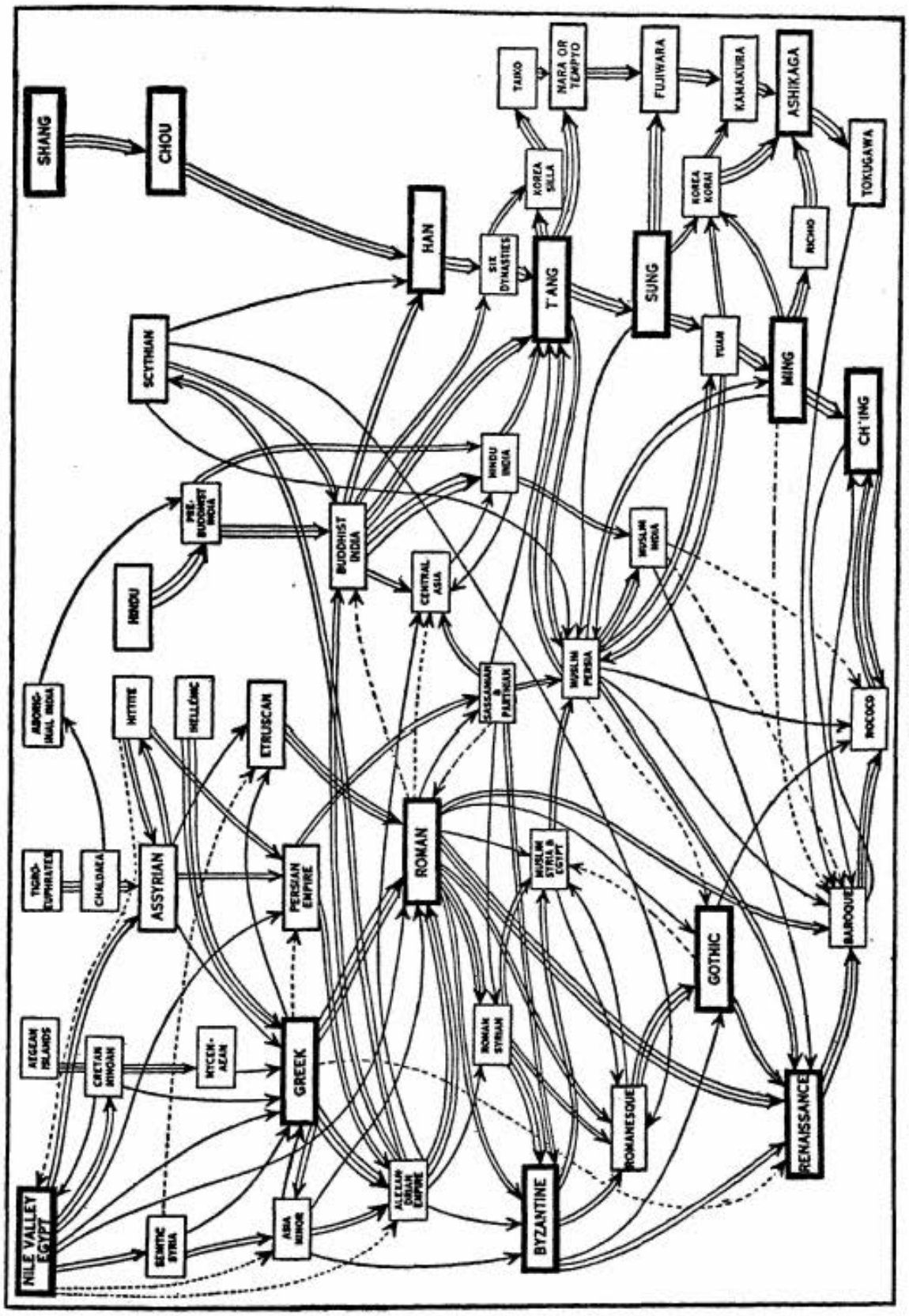
The chart on page 33,* which shows the influence of various schools of art upon one another, is also a guide to the study of the development and interchange of materials and methods used in painting. Modern conditions have brought art to a sort of international era in which the works of all schools, regions, and historical periods are available as influences upon current developments. This has brought about an appreciation and valuation of forms and philosophies foreign to our own, and in a similar way, there are no known methods or materials used by any other school, age, or country that are not available to us if we choose to employ them.

Relation of Early Methods to Modern Practice. The artists' interest in techniques of the past is neither that of the antiquarian nor that of the scientist, nor are they very often concerned with the precise duplication of the technical effects of early painters in order to produce works that will exactly imitate their results. They are primarily concerned with learning as much as they can about their materials and methods so that their opinions as to the durability of works of art may be based on a knowledge of how different types of work have stood the test of centuries under all sorts of conditions. In analysing the procedures of past ages, which were employed to create effects often entirely at variance with current artistic standards, we are interested in adapting them or their principles to our own uses rather than in the mere duplication of the old effects for their own sake.

From the viewpoint of the practising artist all the data which have been accumulated from the two principal sources (literary research and chemical analysis) lead directly to a third source, which is most conclusive and valuable; this lies in the re-creation of these techniques by reconstruction as well as by analysis. We know, for example, that the Egyptians used a size or water-soluble binder with their colours; whether it was gum arabic, glue, or milk is of less concern, and a long and careful study into the matter would be antiquarianism, not valuable research. Similarly we know that stand oil, sun-

* Chronological relationships and geographical arrangement are not shown on this chart. The importance of each period as an influence is indicated by the weight of the outline.

A dotted arrow indicates traces; a single arrow, definite but slight influence; a double arrow strong; and a triple arrow such influence as to be a dominant factor in the period. Arrows running both ways indicate reciprocal influences. In general the terms used are in their broadest interpretations; thus, 'Romanesque' covers Carolingian, as well. (Adapted from the *Encyclopaedia Britannica*, 14th ed., Vol. 17, p. 526, by permission.



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thickened oil, Venice turpentine, and sandarac were used alone and in varying mixtures by the Northern painters as far back as the beginning of the fifteenth century. Should we wish for any reason to duplicate the effects of these painters it matters little which one or which mixture of these materials we use so long as we get the results by obeying the simple and generously flexible rules for permanence in their application. Laurie, Doerner, Eibner, De Wild, and others among the modern writers on painting have expressed definite opinions on these matters; their conclusions may oppose one another in minor details, but they are based on more solid factual foundations than were possible a generation ago. Whether a little egg was added to sun-thickened oil in any specific case or a lot of Venice turpentine, resins, and oil of lavender added to stand oil, is of secondary importance from this viewpoint. The experimental painter is able to draw many conclusions from his experience, and is in as good a position to analyse old methods by an examination of a painting as are many professional experts.

2

Pigments

A pigment is a finely divided, coloured substance which imparts its colour effect to another material either when mixed intimately with it or when applied over its surface in a thin layer. When a pigment is mixed or ground in a liquid vehicle to form a paint, it does not dissolve but remains dispersed or suspended in the liquid. Coloured substances which dissolve in liquids and impart their colour effects to materials by staining or being absorbed are classified as dyes.

Materials used as artists' pigments have requirements other than colour; the term 'pigment properties' is used in this book to refer to structural and other physical properties apart from colour. Powdered materials which become colourless or virtually colourless in paints are called inert pigments.

The various methods of painting—oils, water colour, etc.—differ from one another in the material with which the colour is applied and attached to the ground; the pigments used are the same in all, except that a pigment which is suitable for one purpose does not always meet the requirements for another.

Body Colour and Glaze

Two systems of colouring may be distinguished in our painting methods. One employs comparatively heavy layers of opaque paint or pigment, and obtains its white and pale shades by the admixture of white pigment. This is generally called body colour. The other employs transparent colours, and for whites and pale shades utilizes the white of the ground as in water colours, or glazes for some effects, as in oils.

No strict line can be drawn between the two, for the materials and methods in general use are not entirely one or the other. Transparent painting usually shows some of the body colour effect, and opaque painting often contains some of the other. The two systems may be used together in the same painting whenever the physical nature of the technique permits, but they cannot be mixed indiscriminately, and it must be borne in mind that they are two distinct methods of producing colour effects.

Requirements for a Paint Pigment

1. Should be a smooth, finely divided powder.
2. Should be insoluble in the medium in which it is used.

3. Should withstand the action of sunlight without changing colour, under conditions to which the painting might normally be exposed.

4. Should not exert a harmful chemical action upon the medium or upon other pigments with which it is to be mixed.

5. Should be chemically inert and unaffected by materials with which it is to be mixed or by the atmosphere.

6. Should have the proper degree of opacity or transparency to suit the purpose for which it is intended.

7. Should be of full strength and contain no added inert or loading pigments.

8. Should conform to accepted standards of colour and colour quality and exhibit all the desirable characteristics of its type.

9. Should be purchased from a reliable house which understands and tests its colours, selects them from world-wide sources, and can furnish information as to origin, details of quality, etc.

Classification of Pigments

Pigments may be classified according to colour, use, permanence, etc. It is customary, however, to classify them according to origin, as follows:

A. Inorganic (mineral)
   1. Native earths: ochre, raw umber, etc.
   2. Calcined native earths: burnt umber, burnt sienna, etc.
   3. Artificially prepared mineral colours: cadmium yellow, zinc oxide, etc.

B. Organic
   1. Vegetable: gamboge, indigo, madder, etc.
   2. Animal: cochineal, Indian yellow, etc.
   3. Artificially prepared organic colours: anilines, alizarin, etc.

General Characteristics of These Groups. Artificial mineral colours made with the aid of strong heat are generally of the greatest permanence for all uses, while those requiring delicate or very accurately balanced processing are less so. The artificial counterparts of the red and yellow earths are more brilliant and, if well prepared, superior in all other respects to the native products. Pigments derived from natural vegetable sources are more fugitive and less brilliant than aniline colours. Aniline colours are characterized by a great brilliancy and intensity but for the most part are unsuitable for permanent painting because they are either not light-fast, will bleed in oil, will react with other pigments, or have bad physical or pigment-particle properties.

The native earths used as pigments occur all over the world, but there is always some special locality where each is found in superlative form or where conditions have been established which permit of its being purified to a greater or more uniform extent than is economically possible elsewhere. Substitutes for French ochre, Italian sienna, etc., are offered for reasons other than the purpose of supplying the best available product.

The natural impurities in some red earths are of such a character as to be harmful; therefore the artificial red oxides are preferred to them. The impurities or non-colouring constituents of the highest grades of ochre and the other permanent earth colours seldom present the same disadvantages.

There is some doubt as to the antiquity of the practice of refining, calcining, or otherwise treating the native earth pigments. Under the name of artificial or manufactured cinnabar, Theophrastus[1] described the purification and improvement of a fine variety of native red iron oxide and noted that it was a recent innovation, only 90 years old (fourth century B.C.). All the more complete records from Roman times on, show that the procedures of calcination and levigation of the native earths was common practice. The identification of pigments found in ancient relics is not particularly difficult for the experienced technician and many studies have been made of them.

Lakes. A lake is a pigment which has been made by precipitating or fixing a dye upon an inert pigment or lake base. The process may be compared to that of dyeing cloth and a high degree of skill is required to produce good results. Lakes are made in a great range of hues and strengths; when they are made in the most concentrated form (precipitated alone, as a dye salt, without any base) they are called toners and are not, strictly speaking, lakes. Alumina hydrate is the usual base for clear, transparent lakes such as are used as glazing colours, in printing inks, etc.; while blanc fixe is the best base for those to be used in heavy paints and for similar purposes where more body or opacity is required. Cheaper lakes, less clear in tone, are made on clay, barytes, etc. Green earth is valuable as a base for green lakes, as it is a species of clay which has a strong power of absorption for dyes. A lake can also be made with a coloured pigment as a base.

The dyestuffs in use are coal tar products, although a few of the older extracts of vegetable and animal origin still survive for some special purposes —usually only because of their low cost, for lakes made from modern coal tar colours are greatly superior in every paint requirement to those obtained from the natural colouring extracts. Prior to the eighteenth century, lake usually meant red lake only. The term comes from the Indian *lac* which is described under shellac. Scum or sediment from the dyers' vats, called *lacca* and consisting of dyed particles of shreds, fibres, dust, and other impurities, was collected and used as a pigment in Italy in early times.

Reduced or Let-down Colours. Commercial pigments are supplied for some industrial purposes in grades known as reduced or let-down colours. As a general rule they are condemned for use in artists' paints; none but the purest, most concentrated grades available should be selected for use in permanent painting.

A reduced pigment is not ordinarily diluted with inert filler by the simple admixture of dry powders, but the inert material is usually introduced during the manufacturing process in the wet stage, thereby producing such an intimate mixture that the product has a brighter and less muddy tone than it would have had if the filler had been merely sifted into or ground together with the finished dry colour.

Mass Tone and Undertone. The full strength surface colour of a pigment viewed by reflected light is called its mass or top tone; its colour effect when it is spread out thinly is called its undertone. The undertone is discerned when a transparent colour is spread out on glass and viewed by transmitted light or when an opaque colour is used as a tinting colour, diluted with much white. Some pigments have undertones which are distinctly different from their top tones; this is apparent in the average alizarin when it is viewed in a thin layer on glass held up to the light, or drawn out on paper as described on page 94. Some of the aniline reds in use as industrial printing ink colours have such bluish undertones that they can be used to produce two-toned effects. Other pigments display little or no differences between their top tones and their undertones.

List of Pigments

The following catalogue of pigments with their descriptions is a complete list for reference purposes. Pigments are included whether or not they are fit for artists' use, because many inquiries refer to obscure and little-used colours; this list is followed by a section of approved pigments for the different techniques of painting, which in turn is followed by additional miscellaneous data on the pigments in common use, arranged according to colour.

The dates attributed to the older colours have been arrived at by a study and comparison of the literature on the subject. Some references are mentioned where the dates are obscure. Most of the dates of the more modern colours (eighteenth to twentieth century) have been obtained directly from original sources such as contemporary chemical and technical publications. There is ordinarily an appreciable lapse of time between the discovery of a material and its introduction to the artist's palette. Lists of dates showing the pigments in use in artistic painting during various eras have been published in the works of Laurie,[24] De Wild,[100] Eibner, and others, but none is exhaustive.

Composition of Pigments. It should be noted that the chemical purity of pigments varies greatly; some are simple, almost pure compounds as described; others of equally high quality contain minor components either as natural impurities or as the result of ingredients added during manufacture to modify colour or pigment properties. Except where these are a significant or characteristic element in the composition of the pigment they are usually ignored in its description.

Nomenclature. The nomenclature of pigments is confusing and unsystematic. They are named for their resemblances to objects in nature, for their inventors, their places of origin, the purposes for which they are used, and for their chemical compositions or derivations.

The principal cause of confusion is the labelling of colours with fancy names by manufacturers and others, often for some ulterior motive. This has caused a single colour to be known by a dozen different names and two or more entirely different colours to be known by the same name. Proposed

systems of rational colour nomenclature have never made any great headway.

As a general rule, the manufacturer of a prepared or mixed colour or similar material sold under a trademarked name or under some indefinite designation such as 'permanent green' or 'primrose yellow', is not at all bashful about revealing its true composition when it is made of high-grade, approved ingredients, because he thereby gets credit for the use of correct or expensive raw materials. Products whose composition is kept secret have the disadvantage of being under suspicion.

The name most generally used and accepted by artists and by colour makers has been employed in the following list to head the description of the colour, regardless of its derivation, and all synonyms have been made to refer to it. A few exceptions have been made; in some instances where the chemical name of the colour is in wide enough use to warrant its competition for preference over the still more frequently used common name, it has been adopted; also names such as viridian and aureolin which unmistakably refer to one specific pigment of artists' quality have always been retained. Where a name is purely a synonym and the colours are identical, it is entered thus:

Guignet's green—Viridian.

Where the colour is basically the same but is either made by a different method or possesses somewhat different properties it is listed thus:

Casali's green—Variety of viridian.

Where the variation is sufficiently important to receive specific mention, it is either described in its place or mentioned under the main heading and listed as:

Scheele's green—See emerald green.

The general arrangement of the items in this list is as follows: name of the pigment, its chemical identification, description of its colour, estimate of its value in permanent painting and data on its discovery and introduction to the artist's palette. Details of manufacturing processes are more or less ignored except where they are a significant factor in the description or identification of a pigment.

ACADEMY BLUE. A mixed colour; best grade should be composed of ultramarine and viridian.

ACETYLENE BLACK. See carbon black.

ALEXANDRIAN BLUE. Egyptian blue.

ALIZARIN BLUE. ALIZARIN GREEN. Clear, transparent, brilliant lakes ranging from an indigo blue to an emerald green. These colours are not to be used for permanent painting, although they are employed in printing inks and for other semi-permanent uses. They are similar to alizarin red and violet in composition and will not fade readily, but they turn very dark, almost black, on continued exposure to light.

ALIZARIN BROWN. A rather dull but transparent brown. Its properties are identical with those of alizarin red. The brown may be produced as the

result of an occasional off-colour batch of red. Permanent. See alizarin red.

ALIZARIN CRIMSON. ALIZARIN LAKE. ALIZARIN RED. ALIZARIN SCARLET. Made by developing alizarin, an organic product made from anthracene, a coal tar derivative. They are permanent, being the only organic pigments included in most of the approved lists. Made in a rather limited range of shades from a rosy scarlet to a maroon, all of them have a characteristic bluish undertone and are clear and transparent. They absorb much oil and are slow driers. Will not fade on long exposure to normal daylight but some samples show a tendency to become deeper in shade. Unlike the older madders, the modern high-grade alizarins may be mixed indiscriminately with all the other permanent colours. See madder lake.

ALIZARIN VIOLET. A clear, transparent, brilliant violet which may be made in a variety of reddish and bluish shades. Permanent. Properties are identical with those of alizarin red. Alizarin and purpurin are two closely allied compounds; the violet contains a larger percentage of purpurin.

ALIZARIN YELLOW. A dull, rather brownish, but transparent yellow. Its pigment properties are the same as those of alizarin red, except that it is not so reliably permanent because grades of highest quality are rare on the market.

ALUMINA HYDRATE. Aluminium hydroxide, artificially produced. A white, fluffy, light-weight powder which becomes virtually colourless and transparent when it is ground in oil. It is widely employed as an inert base for lakes, particularly those used in printing inks and in students' grade artists' oil colours. Permanent. Objection to its use in artists' oil colours is based on its high oil absorption and the fact that because of its transparency it does not mask or hide the colour of the oil or the subsequent changes such as darkening of oil. It is often considered by manufacturers to be a necessary addition to some heavy oil pigments for artists' use, because it imparts desirable brushing consistency and stability to tube colours.

AMERICAN VERMILION. A heavy, opaque, coal tar lake, usually made from eosine or scarlet dye on a red lead, orange mineral, or chrome red base. Not permanent. There is great variation of behaviour in different specimens.

ANILINE COLOURS. Made from aniline, a derivative of coal tar. A complete range of brilliant lake colours of every type, few of which are considered for use in permanent painting. Some fade out completely and some are semi-permanent; for instance, those used in house paints will generally last the few years the paint is expected to live, and those for printing inks will last as long as is usually required. When kept from too much exposure to light the better ones used for printing ink are quite adequate. As a general rule, even those of ordinary durability are more permanent than the majority of the older vegetable colours. Extensive use dates from about 1870. See *New Pigments*.

ANTIMONY ORANGE. ANTIMONY VERMILION. Antimony trisulphide. Bright colours, permanent to light and other conditions, but having the fault of

blackening the lead pigments on account of the free sulphur most specimens contain. The orange is light and bulky, the vermilion somewhat heavier; they are rather dull powders in the dry state but bright when mixed with mediums. Obsolete for artistic use; replaced by cadmiums. Patented 1847 by Murdock, England.

ANTIMONY WHITE. Antimony oxide plus about 70% blanc fixe. Preparation and properties similar to those of titanium white; similar claims made for it by the manufacturers. British trademark: Timonox. Introduced in 1920. Permanent, but slightly affected and darkened by sulphur fumes. Unnecessary for artists' use.

ANTIMONY YELLOW. Naples yellow.

ANTWERP BLUE. A pale variety of Prussian blue made by reducing pure Prussian blue with 75% of an inert pigment, usually alumina hydrate; sometimes contains zinc salts. Similar in properties but inferior to pure Prussian blue. Not for permanent painting.

ANTWERP RED. Light red.

ARMENIAN BOLE. A native red earth; see Venetian red.

ARNAUDON'S GREEN. A variety of chromium oxide green.

ARSENIC ORANGE. ARSENIC YELLOW. See realgar and King's yellow.

ARTIFICIAL ULTRAMARINE. See ultramarine.

ASBESTINE. A species of talc (hydrated magnesium silicate) mined in northern New York and used in America as an inert pigment in certain mixed paints. Its physical structure causes it to float or remain in suspension unusually long, and when mixed with heavy pigments it tends to prevent rapid settling and caking in liquid paints. Permanent, but not usually used in artists' paints. Not the same as asbestos, a silicate of different structure.

ASPHALTUM. Not a true pigment colour. A blackish-brown solution of an asphalt in oil or turpentine. At one period it was extensively used as a glazing colour. Dries badly, causes wrinkling and cracking, and develops almost every fault of oil colours, particularly if mixed with other oils and colours. Used for scumbling decorative work to simulate age, but not for permanent painting. Easily imitated by mixtures of permanent colours. Some asphalts are described on page 387. They have been used for protective coatings since prehistoric times; their use in artistic painting began with the rise of oil painting in the seventeenth century.

AUREOLIN. Cobalt-potassium nitrite. A bright, transparent yellow, permanent for water colour, tempera, and oil, especially in glazes and for tinting; as a body colour, its top tone is rather dull, muddy, and greenish. Supersedes gamboge. Compound discovered by N. W. Fischer, Breslau, 1830; first introduced in the form of a paint pigment by Saint-Evre, Paris, 1852; introduced in England about 1860.

AURIPIGMENTUM. King's yellow.

AURORA YELLOW. A variety of cadmium yellow.

AURUM MUSSIVUM. Mosaic gold.

AZURE BLUE. Smalt. Azure was a very early general term for blue. Modern meaning is usually a sky-blue shade of any composition.

AZURE COBALT. A variety of cobalt blue.

AZURITE. Native basic copper carbonate. Rare. Replaced by ultramarine, cobalt, and cerulean blues. Clear, deep blue. Permanent, but often contains malachite as an impurity. Its use as a pigment dates from Roman times. Works very poorly with oil; was used only in aqueous mediums.

AZZURO DELLA MAGNA. Azurite.

AZZURO OLTREMARINO. Ultramarine blue.

BARIUM YELLOW. Barium chromate. A very pale sulphur-coloured yellow with a greenish tone. Somewhat transparent in oil but more opaque than zinc or strontium yellows. Compared with zinc and strontium yellows, the average barium yellow is very low in tinctorial power, and in appearance is like zinc yellow reduced with about 75% of white pigment. Insoluble in water. For all permanent painting. Probably first made soon after chrome yellow in the first quarter of the nineteenth century.

BARYTA GREEN. Manganese green. The term baryta is an obsolete form of barium.

BARYTA WHITE. Blanc fixe.

BARYTES. Native barium sulphate, finely ground, washed, and bleached. A white powder with no colouring power and practically transparent in oil, where it tends to impart muddy tones. Used as an adulterant and inert pigment in cheap paints and colours. Very heavy. Use in paints probably began in eighteenth century. See blanc fixe.

BENZOL BLACK. See carbon black.

BERLIN BLUE. Prussian blue; term used especially in France.

BIACCA. White lead.

BIANCO SANGIOVANNI. Calcium hydroxide plus calcium carbonate. A fresco white, described on page 236.

BICE. See Blue bice and green bice.

BISMUTH WHITE. Bismuth nitrate. Obsolete since the introduction of zinc white. Had a brief and limited use during the early nineteenth century as a less poisonous substitute for white lead. It is more sensitive than white lead to the darkening action of sulphur fumes.

BISTRE. Yellowish-brown soot containing wood tar, made by charring beech wood. Used only as a water-colour wash. Common variety soon fades; better grades fade more slowly, but it is never a reliable, permanent colour. Dates from the middle of the eighteenth century.

BITUMEN. Asphaltum.

BLACK LEAD. Graphite.

BLACK OXIDE OF COBALT. A rather coarse black powder; properties are similar to those of black oxide of iron, but it is not now in use as a paint pigment. Used in ceramic glazes, where it imparts a deep blue colour upon being fired.

BLACK OXIDE OF IRON. Mars black. Ferro-ferric oxide, approximately 1 FeO to 3 Fe_2O_3. A dense, opaque, heavy colour, absolutely permanent for all uses. A native variety also exists, but it is coarse and not suitable for artists' use. It is comparatively brownish in undertone, wets easily, and is non-greasy.

Useful to replace the carbon blacks when these qualities are required. Attracted by magnet. The modern product is a twentieth-century development.

BLACK OXIDE OF MANGANESE. Native manganese dioxide. Seldom produced in a finely ground form suitable for pigment use. Its properties are somewhat like those of black iron oxide except that it is still more brownish and is a powerful drier in oil; its principal use in paints and varnishes is as a raw material to prepare driers and drying oils. The native ore, pyrolusite, was, however, used as a pigment in early civilizations. Artificial manganese oxide is described under manganese black.

BLADDER GREEN. Sap green.

BLANC FIXE. Artificial barium sulphate, very much finer and fluffier than native barytes; they have the same chemical composition but are entirely different in pigment qualities. Used as a base for the more opaque lakes and as an inert pigment in house paints, etc., where, if added in proper proportions (generally 10%), it is not considered an adulterant, as it imparts good weathering qualities. Almost transparent in oil, it is of no use in permanent oil painting, but has been recommended as a water-colour and fresco white, in which mediums it retains its white colour and is permanent. Introduced in the early or middle nineteenth century in France.

BLEU CÉLESTE. Cerulean blue.

BLUE ASHES. See Bremen blue.

BLUE BICE. See Bremen blue.

BLUE BLACK. See vine black.

BLUE MALACHITE. Azurite.

BLUE VERDITER. See Bremen blue.

BOHEMIAN EARTH. Green earth.

BOLE. Various native red oxides of iron or clays coloured with iron.

BOLOGNA CHALK. Slaked plaster of Paris.

BOLOGNA STONE. Barytes.

BONE BLACK. Made by charring bones. Contains only about 15 to 20% carbon, about 60% calcium phosphate, and about 20% calcium sulphate and other impurities, some of which are water-soluble. It should not be used in fresco or for mortar or cement colouring, as it causes efflorescence. Rather fine, light, and fluffy, but somewhat heavier and more compact than lampblack. Very slow drier in oil; stands up fairly well, but the use of a purer black is wiser. Has a brownish undertone as compared to the vine black series. Probably dates from Roman times. See *Black Pigments*.

BONE BROWN. Similar to bone black. Made by partially charring bones, it contains undecomposed animal matter. Not permanent.

BOUGIVAL WHITE. Bismuth white.

BRAZIL WOOD LAKE. Brazil wood yields a blood-red extract which has been used to make dyes and lakes from very early times. It is less permanent than the aniline colours which have superseded it except for some few purposes where its lower cost is a prime consideration. The South Ameri-

can country was named after this product which had long been an article of commercial importance in Europe.

BREMEN BLUE. Copper hydroxide plus copper carbonate. Produced in a number of shades of blue and greenish blue: some delicate and pale; some fairly deep, all semi-opaque. Poisonous. There are a great many variations in the manufacture of this type of copper blue, each product bearing a separate name. Their properties are so familiar, however, that in this list they have all been referred to this heading. Not intended for permanent painting, but semi-permanent for other purposes. They have been superseded by the cheaper grades of ultramarine for most industrial uses. Probably first made early in the eighteenth century, they were widely used in the middle of the nineteenth, and continued in diminishing use until the twentieth century.

BREMEN GREEN. Greenish varieties and green shades of Bremen blue.

BRILLIANT SCARLET. See iodine scarlet.

BRILLIANT YELLOW. Naples yellow.

BRONZE BLUE. Prussian blue, especially those varieties which have a pronounced bronzy sheen.

BROWN LAMPBLACK. Bistre.

BROWN MADDER. See Alizarin brown and Madder lake.

BROWN OCHRE. A dull variety of ochre.

BROWN PINK. A brownish yellow lake of vegetable origin similar to Dutch pink.

BRUNSWICK BLUE. A let-down variety of Prussian blue. Large amounts of barytes are added during manufacture. Sometimes contains a little ultramarine. The name refers to the quality rather than to the exact shade; most of the regular Prussian blue shades may be produced in this grade. Not for permanent painting.

BRUNSWICK GREEN. Chrome green made from Brunswick blue and reduced chrome yellow.

BURNT CARMINE. Variety of carmine, deep and dark. Fugitive.

BURNT OCHRE. Ochre which has been heated in furnaces until it has become brick-red. Permanent, but weak in colour compared with the red oxides. See light red.

BURNT SIENNA. Raw sienna which has been calcined or roasted in furnaces. Compared with the other earth colours, native or artificial, it has the most brilliant, clear, fiery, transparent undertone, and its red-brown top tone is least chalky in mixtures. Permanent. One of the most useful pigments in all techniques.

BURNT UMBER. Made by calcining raw umber. Compared with raw umber it is much warmer, being reddish rather than greenish in tone, darker, and somewhat more transparent. Otherwise the remarks under raw umber apply to it.

BYZANTIUM PURPLE. See Tyrian purple.

CADMIUM COLOURS. Cadmium orange and yellows are cadmium sulphide; cadmium red is three parts cadmium sulphide plus two parts cadmium

selenide. (Selenium is an element whose compounds resemble those of sulphur.) These pigments are made in a variety of shades, all bright, very opaque, and permanent. Most modern cadmiums are made by a method similar to that used for making lithopone and contain barium sulphate (cadmium being a metal closely allied to zinc, the two enter into similar chemical combinations). These cadmium-barium colours or cadmium lithopones are superior in most pigment qualities to the older straight cadmium sulphides and all the shades are permanent to light. Typical examples of the palest yellow shades contain 62%, and the deepest maroon 52%, blanc fixe (not as an adulterant; see lithopone). The cadmium-barium reds are obtainable in a variety of shades, from a close match for vermilion to a deep maroon. Cadmium red is one of the more recent of the permanent colours; introduced by de Haen in Germany in 1907, it came into general use in England after 1919, though Roberson's were supplying it in 1912, and in America in 1919. The yellows were introduced commercially in England in 1846, but it was some years before they were widely accepted. There is some record of their pigment use in France at least fifteen years earlier, in Germany in 1829, and in America in 1842. The salt was discovered in 1817. The cadmiums were slowly adopted because of the former scarcity of the metal; now it is common enough to employ in industrial products.

CALEDONIAN BROWN. A native earth, similar in shade but inferior to burnt sienna.

CALEDONIAN WHITE. Lead chloro-sulphite. Obsolete.

CAPPAGH BROWN. Native Irish earth similar in shade but inferior to umber. Permanent.

CAPUT MORTUUM. Obsolete name for a very bluish red oxide of iron.

CARBON BLACK. Pure carbon made by burning natural gas. An intense, velvety, black pigment, blacker than most of the other forms of carbon such as lampblack, ivory black, etc. Absolutely permanent. Slow drier in oil. Used in intense black coatings; not very much as a tinting colour on account of its tendency to show in black streaks even after considerable mixing or rubbing with other colours. Acetylene and benzol blacks are more intense, softer, bluer varieties than can be made by burning natural gas. Invented in America in 1864, carbon black came into wide use about 1884. Lampblack, ivory black, and all the other varieties of carbon are sometimes grouped and referred to as carbon blacks. See *Black Pigments*.

CARMINE. A fugitive lake made from cochineal, a dyestuff extracted from a Central American insect. Its European use dates from the middle of the sixteenth century. Recipes for its manufacture were published as early as 1656.

CARTHAME. Safflower.

CASALI'S GREEN. A variety of viridian.

CASHEW LAKE. Mahogany lake.

CASSEL EARTH. A native earth containing organic matter, similar to Van Dyke brown. Not permanent.

CASSEL GREEN. Manganese green.

CASSEL YELLOW. A variety of Turner's yellow.

CELADON GREEN. Green earth. This pigment contains the mineral celadonite, an iron silicate. Celadon means a pale or greyish green colour. The Chinese celadon porcelain was named for its resemblance to this general shade.

CELESTIAL BLUE. A variety of Prussian blue, similar to Brunswick blue but usually made on a barytes base. Contains from 5 to 12% of pure Prussian blue. Not for permanent painting.

CERULEAN BLUE. Cobaltous stannate, a compound of cobalt and tin oxides. A bright sky blue, quite opaque. Permanent for all uses. Introduced as a paint pigment by G. Rowney, England, 1870, but known as early as 1805.

CERUSE. Obsolete name for white lead.

CHALK. Artificially prepared calcium carbonate in its whitest, finest, and purest form, usually called precipitated chalk. Of no use as a white pigment in oil, but when used in glue and other aqueous mediums as a ground for oil and tempera paintings, it retains its brilliant white colour. It is the basis of most pastels. Has the same chemical composition as limestone, whiting, and marble, but contains no impurities, and is much whiter, being one of the whitest substances in use. Its wide use is apparently recent, dating from the nineteenth century. Older references to chalk are to native chalk (whiting).

CHAMOIS. Obsolete name for ochre.

CHARCOAL. Vine, willow, and other twigs charred for use as crayons. When powdered, charcoal has poor paint pigment qualities. See vine black.

CHARCOAL GREY. Obsolete grey-black powder made from charcoal. Not suitable for pigment use.

CHESSYLITE. Azurite.

CHESTNUT BROWN. Umber.

CHINA CLAY. Native hydrated aluminium silicate. So called because it is used to make chinaware. As an inert pigment it has a variety of uses; in colours it serves chiefly as an adulterant. Lakes made on a clay base tend to be muddy. Kaolin is a very pure china clay.

CHINESE BLUE. A variety of Prussian blue. Highest quality.

CHINESE INK. India ink.

CHINESE RED. Chrome red.

CHINESE VERMILION. Genuine vermilion made in China.

CHINESE WHITE. Zinc white prepared for water-colour use, introduced in England in 1834.

CHINESE YELLOW. King's yellow. The name has also been applied to bright ochres.

CHROME GREEN. Intimate mixture of Prussian blue and chrome yellow. The blue is made in a tank which contains the yellow, the yellow being used as a base. As there are many varieties of each of these two pigments, a great variety of greens may be produced. Their properties in general are the same

as those of the chrome yellows, plus the defects of Prussian blue. Never used for permanent painting.

CHROME ORANGE. CHROME RED. CHROME YELLOW. Lead chromates. A large variety of shades, from a pale primrose yellow to a deep orange-scarlet, are produced by variations of the process of manufacture. They are opaque, work well with oil, and are used in large quantities in cheap paints. Even the best grades are not permanent, turning dark or greenish. They may also react with some of the other colours. Replaced perfectly by cadmiums for artistic use. Introduced 1797.

CHROMIUM OXIDE GREEN. Chromium oxide. An opaque, cool, rather pale willow green. Not very strong in tinting power. A very heavy powder. Absolutely permanent for all purposes and conditions, including high temperatures. Known since 1809. Introduced commercially as an artists' pigment in 1862.

CHRYSOCOLLA. A native green copper silicate. Like malachite, it was used as a pigment in early civilizations. It was replaced by Egyptian green.

CINNABAR. Native vermilion; much inferior to the manufactured product. Found in relics of Assyrian and other early cultures. European use of ore from Spanish mines dates from an early Greek period. Obsolete.

CITRON YELLOW. Zinc yellow. This term is also applied to any pale greenish yellow. See remarks under primrose yellow.

COBALT BLACK. See black oxide of cobalt.

COBALT BLUE. Compound of cobalt oxide, aluminium oxide, and phosphoric acid. (Imitation cobalt blue, universally used in cheap paints, is a variety of ultramarine.) Bright, clear, nearly transparent, somewhat similar to ultramarine, but never so deep or intense, and with a comparatively greenish undertone. Permanent for all uses. Discovered by Thénard, France, 1802; introduced as an artists' colour 1820–30.

COBALT GREEN. Compound of cobalt zincate and zinc oxide. A fairly bright green, not very powerful, but quite opaque. Has a bluish undertone, is permanent for all uses, and is made in a limited range of shades. Not in wide use. Discovered by Rinman, Sweden, about 1780; introduced as a pigment in 1835.

COBALT ULTRAMARINE. Gahn's blue. A somewhat outmoded variety of true cobalt blue made without phosphoric acid, generally considered inferior to Thénard's blue. Appears violet under artificial light. Permanent, transparent, clear. This name has more recently been applied to the imitation cobalt blue, mentioned under ultramarine.

COBALT VIOLET. Cobalt arsenite (French) or cobalt phosphate (English), the latter variety to be preferred as non-poisonous. A clear, semi-opaque pigment made in a variety of shades, bluish and reddish. It was originally prepared early in the nineteenth century, from a semi-rare native ore yielding a reddish pigment; later it was made artificially and the process was gradually improved until a real violet was developed. Because most cobalt violets contain arsenic it should be handled with caution as a poisonous substance. Permanent. In use since about 1860.

COBALT YELLOW. Aureolin.

COELIN. Cerulean blue.

COERULIUM. Egyptian blue.

COKE BLACK. See vine black.

COLCOTHAR. Pure red oxide; obsolete term.

COLOGNE EARTH. Cassel earth.

CONSTANT WHITE. Blanc fixe.

COPPER BLUE. COPPER GREEN. See Bremen blue.

COPPER CARBONATE. Vert antique.

CORK BLACK. See vine black and Spanish black.

CREMNITZ WHITE. High quality corroded white lead made by a nineteenth-century variation of the Dutch process, litharge being used as a basic raw material instead of metallic lead. See *White Pigments*.

CRIMSON LAKE. A variety of carmine lake. Usually contains a large percentage of alumina hydrate. The term crimson originally referred to kermes.

CYANINE BLUE. A mixture of cobalt and Prussian blues; also the name of an aniline dye.

CYPRUS UMBER. See raw umber.

DAVY'S GREY. Powdered slate.

DERBY RED. Chrome red.

DEVONSHIRE CLAY. China clay.

DIAMOND BLACK. Carbon black.

DIATOMACEOUS EARTH. A form of silica or clay, light, fluffy, and absorbent. The particles are the remains of plant life and under the microscope some varieties exhibit lacy designs which are the skeletons of their original forms. In use as an inert filler.

DINGLER'S GREEN. A variety of chromium oxide green.

DRAGON'S BLOOD. A transparent resin of a blood-red hue; not a true pigment colour. It will dissolve in alcohol, benzol, and some other solvents, but is practically insoluble in turpentine. Not permanent. Used in Europe at least as early as the first century. See *Coloured Resins*.

DUTCH PINK. A fugitive yellow lake made from buckthorn (Avignon or Persian) berries; never intended to be used for permanent painting.

DUTCH WHITE. China clay; also Dutch process white lead.

EGYPTIAN BLUE. Mixture of copper silicates. Egyptian blue is the earliest known artificial pigment, dating in Egypt from about 3000 B.C. The Cretans of the late Minoan period either imported the material or learned the process, and later it was used by the Romans (see Pozzuoli blue). It has long been replaced for paint use by smalt (the process of manufacture being analogous), which in turn has been replaced by the modern cobalt blues. For further description see frit. The true material in improved modern pigment form, originating in France or Germany and sold under the names of Italian and Pompeian blues, is not ordinarily obtainable here, and the bright blue colour of Egyptian faience may be found imitated by coal tar colours under these names.

EGYPTIAN BROWN. Mummy.

EGYPTIAN GREEN. A green variety or greenish shade of Egyptian blue.

EMERALD CHROMIUM OXIDE. Viridian.

EMERALD GREEN. Copper aceto-arsenite. An extremely brilliant green, the only real substitutes for which are the aniline colours. Permanent when used alone or with titanium white, if well protected from the atmosphere with oil and varnish. Not generally recommended for artists' use because it cannot be freely mixed with other colours and because it is extremely poisonous. Discovered by Scheele, Sweden, 1788. The colour called Scheele's green, however, was copper arsenite, an inferior variation, discovered in 1778 and replaced by the industrial production of emerald green during the early years of the nineteenth century. The commercial process for emerald green was introduced in 1814 in Austria.

EMERAUDE GREEN. Viridian.

ENAMEL WHITE. Blanc fixe.

ENGLISH GREEN. Emerald green.

ENGLISH PINK. Dutch pink.

ENGLISH RED. See red oxide.

ENGLISH VERMILION. Genuine vermilion made in England.

ENGLISH WHITE. Whiting.

ESCHEL. A variety of smalt.

EUCHROME. Burnt umber.

FAWN BROWN. Mixture of raw or burnt umber with dark ochre.

FERRITE. FERROX. Manufacturers' trade names for yellow oxide of iron.

FIRE RED. Not a specific pigment. Toluidine red, cadmium red, and others have been so labelled.

FLAKE WHITE. High quality corroded white lead made by the Dutch process. See white lead.

FLAME BLACK. Made by burning coal tar, mineral oils, etc., by a process which produces a grade of carbon inferior to lampblack. Rather brownish, likely to contain oily impurities.

FLEMISH WHITE. White lead.

FLORENTINE BROWN. See Van Dyke red.

FLORENTINE LAKE. Crimson lake.

FOLIUM. An ancient mulberry colour of various vegetable origins. The term was superseded by more exact names of specific lake colours.

FRANKFORT BLACK. Drop black.

FRENCH BLUE. Artificial ultramarine.

FRENCH CHALK. Talc is commonly sold under this name in England and America. French chalk is neither precipitated chalk nor Paris white, which might be suggested by its confusing name.

FRENCH ULTRAMARINE. Artificial ultramarine.

FRENCH VERONESE GREEN. Viridian.

FRENCH WHITE. Silver white.

FRIT. A vitreous substance, such as the blue or greenish-blue glaze on Egyptian faïence, made by melting or fluxing siliceous materials with copper and other metallic salts which impart colour to the mass. The hue of

Egyptian blue frits may be imitated in paints by viridian plus cerulean and cobalt blues. The green phase was probably the result of overburning the blue. The term frit more correcly refers to any melted or fluxed ceramic glaze and may be white or colourless, but in reference to paint pigments it is usually applied to the above material. See Egyptian blue.

FULLER'S EARTH. A form of diatomaceous earth.

GAHN'S BLUE. Cobalt ultramarine.

GALLIOLINO. Naples yellow.

GALLSTONE. Variety of Dutch pink, said to have been made from oxgall; more often it was a yellow lake prepared from quercitron. Obsolete.

GAMBOGE. A native yellow gum from Siam. Transparent. Not a true pigment colour. Not reliably permanent. In use from medieval times to the nineteenth century. Superseded by aureolin for permanent painting. See *Coloured Resins.*

GARANCINE. GARANCE. Madder lake.

GAS BLACK. Carbon black.

GELLERT GREEN. Variety of cobalt green.

GERMAN BLACK. Drop black.

GIALLOLINI. Naples yellow.

GMELIN'S BLUE. Artificial ultramarine.

GOLDEN OCHRE. Ochre brightened by the addition of chrome yellow. Not permanent. See Ochre.

GRAPE BLACK. Vine black.

GRAPHITE. An allotropic form of pure carbon. Principal uses: lead pencils, stove polish, anti-corrosive paint, lubricant. Grayish black, semi-crystalline, flaky, greasy. Permanent but seldom used as an artists' pigment.

GRECIAN PURPLE. Tyrian purple.

GREEN BICE. Green earth; also Bremen green.

GREEN EARTH. A native clay coloured by small amounts of iron and manganese. Occurs in many localities, the best varieties being found in small deposits or pockets. The best European grades are known as Bohemian (pure green tone), Cyprian (yellowish), Verona (bluish), and Tyrolean (similarly bluish, but dull). The supply of the finest kinds is irregular. It is quite transparent and of extremely low hiding and tinctorial power; therefore, it is of slight value as a body colour in opaque oil painting, but is used in glazes and as a water-colour wash. It was popular in Italy from the earliest recorded times, especially in tempera and fresco painting; it is said to have been used by the Romans. It has a peculiarly good absorption for dyes and has therefore been used as a base for some green lakes. Permanent.

GREEN ULTRAMARINE. See ultramarine blue.

GREEN VERDITER. A greenish variety of the copper pigment described under Bremen blue.

GRISAILLE. A pigment consisting of a mixture of burnt umber, red lead, and quartz, used in stained glass. The term has also been used to describe a technique of painting. (See page 433.)

GULF RED. Persian Gulf oxide.

GYPSUM. Native calcium sulphate, an inert pigment of little value in oil paints, except as an adulterant. Very white and sufficiently permanent in water vehicles to be used extensively in the paper and textile finishing trades and sometimes to prepare painting grounds. Its presence (either in native or artificial form) in pigments for permanent oil painting is not generally approved, as it is somewhat water-soluble, generally contains alkaline impurities, and imparts a brittle hardness to oil films.

HAARLEM BLUE. Antwerp blue.

HANSA YELLOW. The trademarked name of a dyestuff from which lakes of remarkable fastness to light may be made. See *New Pigments*. Monolite yellow and Pigment yellow are competitive dyestuffs of the same composition.

HARRISON RED. A trade name applied to several bright cherry reds of the lithol and para red class. When first made, it was much recommended because it was an advance in permanence over the older aniline lakes, but it is not sufficiently light-proof to be used for permanent painting. See *New Pigments*.

HATCHETT'S BROWN. See Van Dyke red.

HEAVY SPAR. Barytes.

HOLLY GREEN. Green earth.

HOOKER'S GREEN. A mixture of Prussian blue and gamboge. Sold in two shades, yellowish and bluish, both of which are rather olive in tone. Not permanent.

HORACE VERNET GREEN. Copper green.

HUNGARIAN GREEN. Malachite.

IMPERIAL GREEN. Variety of emerald green, reduced with inert pigment.

INDIA INK. Lampblack and glue binder, carefully made. Various kinds contain additions to improve colour and working properties. Permanent. See *Inks*.

INDIAN BLUE. Indigo.

INDIAN LAKE. Lac.

INDIAN RED. See red oxide. Formerly this name was applied to a very pure native red oxide from India. Early American painters also used the term to describe a colour typical of an earth used by the Indians.

INDIAN YELLOW. An obsolete lake of euxanthic acid made in India by heating the urine of cows fed on mango leaves. It was a fairly bright, transparent yellow of average tinctorial power, non-poisonous, and was approved by most nineteenth-century investigators as a permanent pigment. Because few of the Indian yellows were genuine and many of the semi-permanent aniline colours were sold under this name, it had, however, fallen into disrepute. The colour has had a long history in India. It seems to have appeared in England about the beginning of the nineteenth century as a material of unknown origin, and its curious method of production did not become known until the eighties. Although its chemical composition was known before that, the pigment has never been reproduced or synthesized on a commercial scale. True Indian yellow has been absent from the market for some time; its production is said to have been prohibited in

1908. At any rate, reliable dealers and manufacturers have replaced it with the more desirable modern light-proof lakes such as Hansa yellow or by aureolin. Cheap colours labelled Indian yellow are coal tar products of varying degrees of permanence.

INDIGO. A deep, transparent blue originally obtained from plants cultivated in India. A better grade has been made synthetically from coal tar since the end of the nineteenth century. It is not entirely light-proof and has long been discarded as a permanent artists' colour. It was used in Europe from very early times, principally as a dyestuff.

INFUSORIAL EARTH. Diatomaceous earth.

INTENSE BLUE. Variety of indigo lake. Recently applied to phthalocyanine blue.

IODINE SCARLET. Mercury iodide. A vivid geranium red, like an aniline colour in brilliance and purity of tone, but much less permanent, fading rapidly to a pale yellow on exposure to light. Extremely poisonous. Useless as a pigment.

IRIS GREEN. Sap green. Originally the name of an obsolete lake made from the juice of iris flowers.

IRON BLACK. Precipitated metallic antimony, not in use as a pigment. Also see black oxide of iron.

IRON BLUE. Prussian blue.

IRON BROWN. Prussian brown.

IRON YELLOW. Yellow oxide of iron.

ITALIAN BLUE. Egyptian or Pozzuoli blue. Name also used for imitations made from lakes or for special shades of Bremen blue.

ITALIAN EARTH. Sienna.

ITALIAN PINK. Variety of Dutch pink.

IVORY BLACK. Impure carbon. Most (and probably all) ivory black on the market is really high grade bone black. True ivory black, carbon made by burning ivory scraps, has the same properties as bone black, but is finer, more intense, and of a higher carbon content—probably because it is made with greater care on account of the value of the raw material. See bone black and *Black Pigments*.

JACARANTA BROWN. Burnt umber.

JAUNE BRILLANT. Naples yellow.

JAUNE D'ANTIMOINE. Naples yellow.

KAOLIN. A pure clay, sometimes used as a filler; very similar to and often the same as the material sold as china clay.

KASSLER YELLOW. Turner's yellow.

KERMES. An obsolete crimson lake made from a dyestuff of insect origin. Used in Roman and medieval times.

KERNEL BLACK. Vine black.

KIESELGUHR. A variety of diatomaceous earth.

KING'S BLUE. Cobalt blue; formerly smalt.

KING'S YELLOW. Arsenic trisulphide artificially made. Originally it was made by powdering the native mineral, orpiment. Very bright yellow; opaque;

works well in oil. Very poisonous. Not reliably permanent. The native orpiment is said not to be poisonous, or at least not dangerously so, and was freely used in the earliest civilizations. These materials, extensively used throughout the history of art, have become obsolete since the introduction of the cadmium yellows. The artificial varieties were probably introduced in the early eighteenth century.

KREMS WHITE. Cremnitz white.

LAC. Not a true pigment. A resin with a deep, transparent, brownish-red colour. Not permanent. Obsolete, having been replaced by alizarin. Used since early medieval times. Described under shellac.

LAKE BASE. Both blanc fixe and alumina hydrate are given this name. See page 37. See also definition in the glossary.

LAMPBLACK. Pure carbon. A fine, light, fluffy powder obtained by collecting the soot from burning oils, fats, etc. The most familiar and widely used of the carbon black group. Permanent for all paint purposes. In use since the earliest periods. See *Black Pigments*.

LAPIS LAZULI. See ultramarine.

LAZULINE BLUE. Native ultramarine.

LEAF GREEN. Chrome green.

LEEK GREEN. Chrome green.

LEIPZIG YELLOW. Chrome yellow.

LEITHNER BLUE. Variety of cobalt blue.

LEMON YELLOW. Barium yellow. Also a general term in common use for a pale yellow shade, rather than a designation for a pigment of any particular composition, and often applied indiscriminately to pale chrome, zinc, or cadmium yellows and others. See remarks under primrose yellow.

LEYDEN BLUE. Variety of cobalt blue.

LIGHT RED. This term is rather loosely applied to calcined ochres and the more intense pure oxides of the Mars or English red type, but originally it was intended to describe a good grade of burnt ochre of a shade between Indian red and Venetian red. Permanent, but the native variety not so desirable as the pure red oxides, which are cleaner and more powerful.

LIME BLUE. See Bremen blue.

LITHARGE. Lead monoxide. A heavy, yellowish powder, obsolete as a paint pigment, used as a drier in varnish cooking.

LITHOL RED. A semi-permanent aniline pigment, bright cherry red with a bluish undertone, used in industrial paints and in printing inks; not for permanent painting.

LITHOPONE. Zinc sulphide 30% barium sulphate (blanc fixe) 70%, intimately combined by chemical means, the blanc fixe being coalesced with and becoming an integral part of the pigment, not an adulterant. Greater proportions of zinc sulphide do not always improve it. A fine, white, opaque pigment which has largely replaced zinc oxide for interior house paints because of its good structural properties and its lower cost. Originally lithopones had the defect of turning dark on one day's exposure to sunlight, becoming bright again after a night's darkness. Modern methods of manu-

facture have minimized this photogenic property, but lithopone is usually conceded to be unreliable as an artists' pigment, although generally approved for use in grounds. Some manufacturers have added it to artists' zinc white in order to impart opacity or hiding power. Lithopones came into wide industrial use early in the twentieth century. Their development was gradual; the first patent (Orr's white) was issued in 1874.

MADDER LAKE. Originally prepared from the root of a plant (*Rubia tinctorum*), but now made artificially from alizarin. Best-quality modern alizarin colours are superior to the native product in most respects; however, some very exacting painters claim that the delicacy of the true madders in very thin glazes is not exactly duplicated but only approximated by alizarin. The name madder is now freely applied to the alizarin colours. Madder was known from the earliest times; alizarin began to replace it after 1870. As dry colours the true madder lakes have almost, but not entirely, disappeared from the American market.

MAGENTA. A fugitive lake made from fuchsine, an aniline dyestuff.

MAGNESIA WHITE. A name sometimes applied to native magnesite and sometimes to the artificial magnesium carbonate.

MAGNESITE. Magnesium carbonate used occasionally as an inert pigment. Permanent. Properties similar to those of whiting. Calcined magnesite is an entirely different material; see page 407.

MAGNESIUM CARBONATE. Artificially made. Probably the very whitest inert pigment. Sold in two forms: heavy, which has properties similar to those of precipitated chalk; and light, which is an extremely bulky, light, fluffy powder of the same chemical composition.

MAHOGANY LAKE. A red or brown lake made on a burnt sienna base, not reliably permanent. Burnt umber and the deeper shades of burnt sienna are sometimes used as mahogany oil stains, and hence sometimes go by the name of mahogany brown.

MALACHITE. Native basic carbonate of copper. Fine, clear, yellowish-green. Used as a pigment by earliest civilizations. Not reliably permanent. Also made artificially. See Bremen blue.

MANGANESE BLACK, MANGANESE BROWN. Manganese dioxide, prepared artificially. Permanent. Extremely powerful drier in oil. Not in common use. Patented as a pigment by Rowan, England, 1871. The native variety is listed under black oxide of manganese.

MANGANESE BLUE. Barium manganate. A permanent greenish light blue similar to cerulean blue, but brighter and cleaner. It has long been known that a number of such compounds will produce permanent greens and blues but few if any have been in practical use until the recent introduction of manganese blue (see page 92).

MANGANESE DIOXIDE. Manganese black.

MANGANESE VIOLET. Made by combining manganese chloride, phosphoric acid, and ammonium carbonate. A permanent violet colour resembling cobalt violet and having the same general properties. Introduced in Germany in 1868. Not ordinarily available.

MAPICO COLOURS. Trademarked name of a series of permanent Mars colours.

MARBLE DUST. Native calcium and/or magnesium carbonate, described on page 237.

MARC BLACK. Vine black.

MARS COLOURS. Artificial oxides of iron. The variation in shades and hues is due to processes of manufacture. All are absolutely permanent and have the same general properties as the pure red oxides. Mars brown contains some manganese. Mars black is described under black oxide of iron, Mars yellow under yellow oxide. The Mars reds are sold in a number of shades from a bright scarlet to a very bluish variety known as Mars violet.

MASSICOT. An obsolete yellow oxide of lead, similar to litharge; usually deeper or more pinkish in hue. Never was considered permanent.

MAUVE. A fugitive lake made from aniline. A variety of very brilliant lakes is made in two groups, reddish and bluish. Mauve was the first aniline colour produced. Discovered and introduced by Perkin, England, 1856.

MERCURY YELLOW. Basic sulphate of mercury. Obsolete. See turpeth mineral.

MILORI BLUE. Prussian blue. The term is usually applied to the purest and highest quality grades.

MINERAL BLACK. A name variously applied to graphite, native black iron oxide, vine black, and artificial black oxide.

MINERAL BLUE. Azurite. Antwerp blue has also been sold under this name.

MINERAL BROWN. Burnt umber.

MINERAL GREY. Ultramarine ash.

MINERAL GREEN. Malachite. Also Bremen green.

MINERAL LAKE. Potter's pink.

MINERAL TURBITH. Turpeth mineral.

MINERAL VIOLET. Ultramarine violet.

MINERAL WHITE. Gypsum.

MINERAL YELLOW. Turner's yellow.

MINETTE. Ochre.

MINIUM. Red lead. The use of this term for this material developed during the Middle Ages; earlier, the Romans had applied it to their native vermilion, cinnabar, and to a lesser extent, to a refined red oxide. Perhaps because some cinnabar was adulterated with red lead and sold as a cheaper variety, the term minium was gradually more specifically applied to this mixture, and eventually to straight red lead.

MITTIS GREEN. Copper arsenate, a variant of Scheele's green.

MITTLER'S GREEN. A variety of viridian.

MONASTRAL COLOURS. Trademark name for phthalocyanine colours.

MONOLITE YELLOW. Hansa yellow.

MONTPELIER GREEN. Verdigris.

MONTPELIER YELLOW. Turner's yellow.

MOSAIC GOLD. Metallic powder of complex composition, principally bisulphide of tin. Formerly used as a cheap substitute for powdered gold. Replaced by modern bronze powders.

MOSS GREEN. Chrome green.

MOUNTAIN BLUE. Azurite; also Bremen blue.

MOUNTAIN GREEN. See Bremen blue. The name was also formerly applied to native malachite.

MUMMY. Bone ash and asphaltum, obtained by grinding up Egyptian mummies. Not permanent. Its use was suddenly discontinued in the nineteenth century when its composition became generally known to artists.

MUNICH LAKE. Carmine.

MYRTLE GREEN. Chrome green.

NACARAT CARMINE. Best grade of carmine. Obsolete.

NAPLES YELLOW. Lead antimoniate. A heavy, semi-opaque yellow, made commercially in limited amounts in about six shades, from a greenish yellow to a comparatively pinkish orange yellow. Made artificially since at least the fifteenth century. Its history is rather obscure and some of the synonyms referred to in this list are not well established as being identical. Cennini supposed it to be a native volcanic earth from Vesuvius. Similar antimony yellows have been found in Babylonian tiles dating back to the fifth century B.C. Permanent, except that the usual precautions for the use of lead pigments apply to it. Often imitated, especially in the cheaper grades of tube colours, by mixtures such as zinc oxide, cadmium yellow, and ochre.

NATIVE GREEN. Native chromium oxide. Obsolete.

NEUTRAL ORANGE. A blended or mixed colour. If pure, should be composed of cadmiums and red oxide.

NEUTRAL TINT. A greyish-violet prepared water colour which should be composed of India ink, Chinese blue, and a small amount of alizarin.

NEW BLUE. Name applied originally to a variety of cobalt blue which contains chromium, but special shades of ultramarine are also sold under this name.

NITRATE GREEN. A modern blue-toned variety of chrome green.

OCHRE. A native clay, which is coloured by iron oxide. Produced in a large variety of dull yellow shades. Opaque. Absolutely permanent. The best, most carefully washed and refined grades come from France. Its use dates from prehistoric times. Golden ochre is ochre brightened by the addition of chrome yellow and is therefore not a permanent colour. Transparent gold ochre is a name used by some artists' material makers for a permanent colour which is either ochre mixed with alumina hydrate or a native ochre which is naturally transparent. See *Yellow Pigments*.

OIL BLACK. Lampblack.

OIL GREEN. Bremen green; also a variety of chrome green.

OLEUM WHITE. Lithopone.

OLIVE GREEN. A designation which may be in use for any one of many mixtures. Applied principally to certain chrome greens.

ORANGE MINERAL. A lead oxide, very similar to red lead, but more yellowish, paler, and not quite so heavy. Less reactive in oil and more suitable for pigment colour use than red lead.

ORANGE VERMILION. A variety of real vermilion.

ORIENT YELLOW. A variety of deep cadmium yellow.

ORPIMENT. See King's yellow.

OSTRUM. Roman name for Tyrian purple.

PAYNE'S GREY. A mixture of ultramarine, black, and ochre, usually sold only as a prepared water colour.

PANNETIER'S GREEN. Viridian.

PARA RED. Paranitraniline toner or lake. A bright cherry red, fairly permanent for industrial use. Bleeds in oil. Its undertone is bluish and less clear than those of other aniline reds. It is not used in permanent artistic painting.

PARIS BLACK. An inferior grade of ivory black.

PARIS BLUE. A general term for Prussian blues, term used especially in Germany.

PARIS GREEN. Common name for emerald green, generally applied when the powder is used for purposes other than pigment—for instance, as an insecticide.

PARIS WHITE. See whiting.

PARIS YELLOW. Chrome yellow.

PASTE BLUE. Prussian blue.

PATENT YELLOW. Turner's yellow.

PERMALBA. Trade name for a prepared artists' white.

PERMANENT BLUE. Not an acceptable term. Usually applied to special shades of artificial ultramarine, but sometimes to an aniline colour.

PERMANENT GREEN. When prepared by a reliable manufacturer, this is a mixture of various permanent greens and yellows in oil or water colour. As the artist can easily mix these pigments himself and as the products sold under such an unstandardized name may be inferior, its use is not always wise. However, some manufacturers who use such names state the complete composition on their labels. Victoria green is sometimes called permanent green.

PERMANENT VIOLET. Manganese violet.

PERMANENT WHITE. Blanc fixe.

PERMANENT YELLOW. Barium yellow. The name permanent yellow is not widely accepted as a specific term and is no certain guarantee that barium yellow is meant; it may refer to some of the semi-permanent or modern light-proof aniline colours.

PERSIAN GULF OXIDE. A variety of native red oxide of iron, usually containing 25% silica.

PERSIAN ORANGE. Lake made of aniline colour on a barytes or blanc fixe base. Not permanent.

PERSIAN RED. English red. Also a variety of chrome red.

PHTHALOCYANINE BLUE. A lake made from organic dyestuff, copper phthalocyanine—a recent development that has shown a remarkable degree of permanence and has been adopted as suitable for artistic use. In order to be used in oil it must be mixed with inert pigment to overcome the coppery bronze of its mass tone and because its tinctorial power when used full strength is too great for convenient handling. When diluted, its tints are different from those of ultramarine or cobalt, more nearly resembling those

of Prussian blue, but quite distinct in colour quality. It appears rather reddish in concentrated paste form because of its coppery bronze top tone, but is a comparatively greenish blue when painted out. In many cases it can be used to supplant the less desirable Prussian blue. Introduced in England in 1935 and known under the trade name *Monastral* Blue and *Winsor* Blue. See *Blue Pigments*.

PHTHALOCYANINE GREEN. A green variety of the above.

PIGMENT YELLOW. See Hansa yellow.

PINE SOOT BLACK. A variety of lampblack, pure carbon.

PLESSY'S GREEN. A variety of chromium oxide green.

PLUMBAGO. Graphite.

POLIMENT. Bole, native red oxide.

POMPEIAN RED. A variety of Indian red.

POTTER'S PINK. Stannic (tin) oxide roasted with various other metallic oxides to produce several variations of pure, but not very intense, pink colour. Used in ceramics and of interest to fresco painters, who may welcome it on account of their limited palette. Permanent but not of sufficient tinctorial power to be worth using in other techniques. Not ordinarily available. See remarks on ceramic colours.

POZZUOLI BLUE. Egyptian blue. According to Vitruvius, the process was brought from Egypt to Pozzuoli in Italy, via Alexandria.

POZZUOLI RED. This name is applied by fresco painters to a red earth originally produced at Pozzuoli (Puteoli)—a species of clay or natural cement capable of setting to a hard plaster-like mass when mixed with water. Both the high-grade artificial red oxides and a native earth of a peculiar rosy shade have been sold under this name. The modern fresco painter is more interested in the hue of Pozzuoli red than in its setting properties, which in fresco might be a defect rather than an advantage. See page 75.

PRIMROSE YELLOW. The name primrose is generally used to designate the very lightest or palest shade of yellow and is indiscriminately applied to chrome yellows, zinc yellows, aureolin, etc. The continued use of names of this type adds to the confusion of pigment nomenclature.

PRUSSIAN BLUE. Ferric ferrocyanide. Deep greenish-blue, unlike other blues; transparent and of extremely high tinctorial power. A great variety of shades exist, depending on variations in manufacture. The concentrated colour has a bronze sheen. Large quantities of the cheaper grades are used in commerce. The finest grades, which are rare on the market, are fairly permanent except when used in thin coats and glazes, or excessively diluted with white. As regards absolute permanence, Prussian blue is one of the 'border line' colours. See *Blue Pigments*. It is destroyed by high temperatures. A large number of names are given the various shades and grades; the most generally accepted names for the best qualities in England and America are Chinese blue and Milori blue. Discovered by Diesbach, Berlin, 1704; introduced as a pigment about 20 years later; process first made public by Woodward, England, 1724. See *Blue Pigments*.

PRUSSIAN BROWN. Iron (ferrous) hydroxide (Indian red in its raw or un-

burned state). Formerly made by burning Prussian blue. Opaque, permanent, but not ordinarily used as a pigment. Is a powerful drier and is so used in the preparation of patent leather and oilcloth oils, where it has desirable properties.

PRUSSIAN GREEN. Brunswick green.

PRUSSIAN RED. English red.

PUMICE. Powdered volcanic rock. A greyish inert pigment sometimes used to impart tooth to grounds.

PURE SCARLET. Iodine scarlet.

PUREE (PWREE). Crude Indian yellow.

PURPLE OF THE ANCIENTS. See Tyrian purple.

RAW SIENNA. A native clay which contains iron and manganese. Best grades come from Italy. Absolutely permanent. Colour similar to that of ochre but more delicate and less opaque.

RAW UMBER. A native earth. Its composition is similar to that of sienna but it contains more manganese. A dark brown, its tones vary from greenish or yellowish to violet-brown. Not entirely opaque. Absolutely permanent. Good grades come from Italy; the best grade (Turkey umber) comes from Cyprus. See burnt umber.

REALGAR. Native arsenic disulphide; reddish-orange; poisonous. It occurs in small deposits in all parts of the world and was used in very early times; has been found in relics of most of the primitive civilizations. An artificial variety similar to King's yellow was also made. Survived until the late nineteenth century; now obsolete, replaced by cadmiums. See King's yellow.

RED LEAD. Composed of lead monoxide and lead peroxide. A very opaque, heavy, brilliant scarlet red. Its colour darkens on exposure; in oil it brushes out poorly. No longer in wide use as an artistic or decorative pigment. Industrially, it is widely employed for its physical and chemical properties; it is used in oil as a priming coat for steel and is valued as a powerful drier. Was made by the Greeks and Romans; one of the earliest artificial pigments.

RED OCHRE. Native red clay containing oxide of iron. See Venetian red.

RED OXIDE. Manufactured iron (ferric), Fe_2O_3. Many shades, all brighter, stronger, finer, and more permanent than the native products described under Venetian red. They replace the native iron oxides for most uses. Very opaque, absolutely permanent. The best grade bluish shades are called Indian red; the yellowish or scarlet shades, light red. A very bluish or purplish oxide, known as Mars violet, is also made. There is considerable confusion in the nomenclature of the red oxides; the terms given in this list are those most widely accepted in the dry colour industry. See *Red Pigments*.

RINMAN'S GREEN. Cobalt green.

RISALGALLO. Realgar.

ROMAN OCHRE. Variety of ochre.

ROSE MADDER. Term applied to a grade of madder or alizarin lake very much weaker than the colour sold as alizarin crimson or madder lake.

ROSENSTIEHL'S GREEN. Manganese green.

ROSE PINK. Weak, fugitive lake made from Brazil wood.

ROUGE. Artificial red oxide of iron, very finest and smoothest grain, any shade. Polishing rouges may often be brownish off-shades, unsuitable for pigment use.

ROYAL BLUE. A 'fancy' name which has been variously applied to smalt, to a variety of artificial ultramarine, and to numerous aniline lakes.

ROYAL GREEN. Chrome green.

ROYAL RED. Aniline lake, made from eosin. Fades rapidly.

ROYAL YELLOW. King's yellow.

RUBENS BROWN. A variety of Van Dyke brown.

RUBENS MADDER. An alizarin red with a bright, clean, brownish-orange tone. See alizarin brown.

SAFFLOWER A fugitive red lake made from dried flower petals of the safflower plant (*Carthamus tinctorius*). This name also applied to zaffer.

SAFFRON. An obsolete bright yellow colour obtained from the dried petals of *Crocus sativus*. Fades badly in daylight. Used in Roman times.

SANDARACA. Some confusion surrounds the early history of this term which was used by the Greeks and Romans to describe orpiment, realgar, and also sometimes cinnabar, the red earths, and a lead oxide yellow. Since medieval times, however, the term sandarac has been applied exclusively to a varnish resin.

SAP GREEN. A lake made from unripe buckthorn berries. Fades rapidly.

SATIN WHITE. A mixture of alumina hydrate and gypsum, used in the manufacture of coated paper.

SATURNINE RED. Red lead.

SAXON BLUE. Smalt.

SCARLET LAKE. The old scarlet lakes were semi-transparent compounds of cochineal lakes and vermilion; the modern ones are aniline colours made from dyestuffs of the same name. Not permanent.

SCARLET VERMILION. Vermilion.

SCHEELE'S GREEN. See emerald green.

SCHNITZER'S GREEN. A variety of chromium oxide green.

SCHWEINFURT GREEN. Emerald green.

SELENIUM RED. Cadmium red.

SEPIA. Prepared from the ink-sacs of various cephalopodous animals, principally the cuttlefish. Semi-transparent, very dark brown, powerful; may be diluted to a variety of tones and shades. Used only as a water colour or ink. Not entirely permanent to light. See *Brown Pigments*.

SHALE. See slate black.

SICILIAN BROWN. Raw umber.

SIENNA. See raw and burnt siennas.

SIGNAL RED. A variety of para red.

SIL. The Attic sil mentioned by Pliny was a fine native ochre.

SILEX. Silica.

SILICA. Native silicon dioxide; powdered quartz. An inert pigment, coarse

texture, no colouring power. Permanent, but not ordinarily employed in artistic painting. Used in grounds and in industrial mixed paints to impart tooth and as an adulterant. Sold in many degrees of coarseness.

SILVER WHITE. This name has been applied to so many pigments that it has little meaning as a designation for any specific white. Manufacturers and writers confer it upon zinc white, modern process white lead, and various mixed whites.

SINOPE. Sinoper or sinopia. An ancient name for all native red iron oxides.

SKY BLUE. Pale artificial ultramarine.

SLATE BLACK. Powdered slate or shale, one of the earliest black pigments used in water mediums. A rather greyish black with poor opacity and low tinting power compared with the carbon and iron blacks. It is still obtainable, being used for some industrial purposes, but is always very coarse and has poor physical properties. Its hardness destroys the surfaces of grinding mills; it is, therefore, never ground very fine. Red, green, and grey slate powders are also made. Permanent, but of small value as a pigment. A shale black containing 15% of carbon is made by calcining bituminous shale.

SMALT. A kind of cobalt blue glass or frit, made by roasting a cobalt ore with other ingredients, much as the Egyptian blue frit was made; in fact, historically, it is considered a direct continuation of the Egyptian colour, the improvement being the substitution of cobalt for the more poisonous and less desirable copper. Cobalt has been found as an ingredient in various ancient blue ceramics, and also as an accidental impurity in the copper blues, but pigments derived from cobalt ores were a Northern innovation. During the height of its importance, before the introduction of artificial ultramarine, smalt was most carefully made in a number of standard grades, but today it finds only a limited use in ceramics and as a sign-painters' material. Its faults were its coarseness, its lack of tinctorial power, and the presence of alkaline impurities. It dates from the middle of the seventeenth century; prior to that, according to Laurie,[24] the name simply meant a frit or ceramic glaze of any colour.

SMARAGD GREEN. Viridian.

SNOW WHITE. Zinc oxide.

SOLUBLE BLUE. A variety of Prussian blue which dissolves in water. Used for ruling lines on writing paper and as a laundry blue.

SPANISH BLACK. Charcoal made from cork; also slate black.

SPANISH BROWN. Burnt umber.

SPANISH RED. See Venetian red.

SPANISH WHITE. Paris white in lump form. This name was also formerly applied to the now obsolete bismuth white.

STEEL BLUE. Prussian blue.

STONE GREEN. Green earth.

STRONTIUM WHITE. Both artificial and native strontium sulphates have the same properties as blanc fixe and barytes, strontium being an element

closely resembling barium. Entirely superseded by the barium whites, which are much less expensive.

STRONTIUM YELLOW. Strontium chromate. A pale, bright yellow with a rather greenish tone, very similar to zinc yellow, usually brighter and somewhat more opaque. It is insoluble in water and permanent for most paint purposes. More expensive than zinc yellow. Although the compound has long been known, its application to pigment use is rather recent.

SUBLIMED WHITE LEAD. A basic lead sulphate which contains zinc. A dense white with many of the characteristics of flake white but inferior as regards low oil absorption, brushing qualities, colour, and stability in mixtures with other pigments. It surpasses flake white in opacity, is not so poisonous, and turns dark less readily on exposure to sulphur fumes. See *White Pigments*.

SUNPROOF COLOURS. The word sunproof indicates a modern aniline colour and is likely to denote one of the recently developed and improved lakes discussed under *New Pigments*. It is a manufacturers' descriptive term rather than the name of a specific pigment.

SWEDISH GREEN. See emerald green.

TALC. A native magnesium silicate used for its slippery or soapy effect and as a filler for various industrial purposes.

TERRA ALBA. Gypsum.

TERRA COTTA. A mixed pigment composed of burnt umber, red oxide, and chalk, in varying proportions; barytes, zinc oxide, or lithopone may replace the chalk; the colour is intended to imitate the natural reddish colour of terra cotta clay.

TERRA MERITA. Fugitive yellow lake made from saffron or curcuma root. Obsolete.

TERRA OMBRE. Raw umber.

TERRA ROSA. Venetian red.

TERRE VERTE. Green earth.

THÉNARD'S BLUE. True cobalt blue.

TIMONOX. See antimony white.

TIN WHITE. Stannic (tin) oxide, used to produce an opaque white in ceramics; not a paint pigment.

TITANIUM GREEN. A dark green, analogous to Prussian blue, made with titanium or a mixture of iron and titanium compounds instead of with pure iron salts. Not in use; probably never made commercially.

TITANIUM OXIDE. Titanium dioxide. An extremely dense, powerful, opaque white of high refractive index and great hiding power. Absolutely inert, permanent. Properties known since 1870 or earlier, but not successfully produced in a pure white grade until 1919 in Norway and America. See *White Pigments*.

TITANIUM PIGMENT. Titanium dioxide 25%, blanc fixe 75%. Composition similar to that of lithopone. Opaque, permanent. See *White Pigments*.

TITANOLITH. Trademarked name for a composite pigment, titanium white plus lithopone. Suitable for use in grounds.

TITANOX. Trademarked name for titanium whites.

TOLUIDINE RED. Paratoluidine toner. Brilliant, rather yellowish fire-red. One of the more permanent of the aniline colours. Used in industrial paints, but not for permanent painting.

TRANSPARENT COPPER GREEN. An obsolete fused copper resinate used in medieval times. See pages 148–9.

TRANSPARENT GOLD OCHRE. See ochre.

TRANSPARENT OXIDE OF CHROMIUM. Viridian.

TURBITH. Turpeth mineral.

TURKEY BROWN. Raw umber.

TURKEY RED. Native red oxide. (Also applied to madder-dyed textiles.)

TURNBULL'S BLUE. Potassium ferrous ferricyanide. A little-used variety of Prussian blue.

TURNER'S YELLOW. Lead oxychloride. Obsolete. A variety of shades from bright yellow to orange were formerly made. Judging by the attention given to it in books of the early nineteenth century and by its large number of synonyms, it was used to a considerable extent. Not permanent; turns black. Patented by James Turner, England, 1781.

TURPETH MINERAL. Basic sulphate of mercury. Bright yellow. Not permanent; turns black. Highly poisonous. Not in use.

TURQUOISE BLUE. Manganese blue.

TURQUOISE GREEN. Compound of aluminium, chromium, and cobalt oxides. A rather pale, clear green of very bluish tone. Permanent for all uses. Quite rare and expensive; imitated by colours which do not resemble it very closely. Finds a small use in ceramics.

TUSCAN RED. A rich maroon lake made on a red oxide base. When expressly stated to be composed of alizarin and Indian red, it is permanent; otherwise it always contains aniline colours and inferior earths. This pigment is employed principally for industrial purposes.

TYRIAN PURPLE. The celebrated imperial purple of the Romans and that used by the Greeks and other ancient peoples was prepared from the shellfish *Murex trunculis* and *Murex brandaris*. In 1908, Friedlaender discovered that the colouring matter of the ancient purple was identical with a purple coal tar colour that had been introduced in 1904. Neither this particular coal tar colour nor the murex purple is in use today because other purples superior in every respect can be made at lower cost. According to Pliny, the most desirable shades of murex purple varied from the reddish or pinkish to the bluish or violet, according to the fashion of the times, and pigments made from it were used principally as glazing colours. The bluish shade was also known as Byzantium purple.

ULTRAMARINE. Originally this pigment was made by grinding a semi-precious stone, lapis lazuli, and purifying it by a complex and difficult process, thus removing all the grey rock with which it is usually associated. Genuine or lapis ultramarine is a rich, deep 'true blue' of practically uniform hue. It has been found in Assyrian and Babylonian relics but only as a decorative or precious stone. Its European use as a pigment began in

the twelfth century; it has always been one of the costliest and most precious of painting materials. Lapis lazuli occurs in Persia, Afghanistan, China, Chile, and a few other countries; it is more often found in the form of blue particles and veins scattered through a grey rock than in the solid pieces which are used in jewellery and ornaments. Investigators believe that lapis is the sapphire of the Bible and other early writings, including those of Theophrastus and Pliny. Since 1828, the ultramarine of commerce has been an artificial product made by heating clay, soda, sulphur, and coal in furnaces; the colour of the resulting compound is attributed to colloidal sulphur. Best grade ultramarines are produced in a wide variety of shades, from that of the true ultramarine blue to imitation cobalt and turquoise shades which are comparatively greenish. The pigment called green ultramarine is a rather dull colour with properties the same as those of ultramarine blue; it is produced during the manufacture of the blue, and may be considered unfinished ultramarine blue; it is not widely used. All pure ultramarine pigments and variations are equally permanent, but many inferior and reduced grades are made for industrial uses. Ultramarine is semi-transparent; it works poorly in oil, where it tends to yield stringy instead of buttery pastes. It is entirely permanent for most uses, including high temperature processes, but is easily affected and bleached by very weak acids and acid vapours; the same is true of the native lapis. After several independent discoveries concerning the nature of the product and the method of its manufacture, it was first produced commercially in France by Guimet in 1828, and the pigment was used by artists in Paris. In the same year the process was published by Gmelin in Germany.

ULTRAMARINE ASH. A delicate blue-grey pigment of slight tinting power. Consists of lapis lazuli mixed with the greyish rock with which it is found in nature. Permanent, but of limited value.

ULTRAMARINE GREEN, RED, VIOLET, YELLOW, ETC. By variations in the ingredients and process, ultramarine pigments of many hues can be produced. They are all very pale and of slight tinctorial power, and although they equal the blue in permanence and resistance to heat, they find far fewer applications in painting processes. The red and violet are pinkish and lavender colours, their use in oil limited to glazes and pale tints; in aqueous mediums they are somewhat more useful. Their physical, chemical, and pigment properties are similar to those of the blue. Barium yellow was formerly misnamed yellow ultramarine.

UMBER. See raw umber and burnt umber.

URANIUM YELLOW. Uranium oxide. A permanent, expensive colour used to some extent in ceramics. Obsolete in paint use. The typical uranium colour is a transparent yellow with a green fluorescence.

VAN DYKE BROWN. Native earth, composed of clay, iron oxide, decomposed vegetation (humus), and bitumen. Fairly transparent. Deep-toned and less chalky than umbers in mixtures. One of the worst driers in oil. Some specimens fade, and in oil this pigment always turns dark, cracks, and causes wrinkling, exhibiting the same defects as asphaltum, but to a

somewhat lesser degree. Not for permanent oil painting. Some of the light-proof grades may be used in water colour and pastel. Dates from the seventeenth century.

VAN DYKE RED. Copper (cupric) ferrocyanide. A poisonous colour with a composition similar to that of Prussian blue, copper replacing the iron. It is fast to light, but blackens when exposed to sulphur fumes. Brownish red, reddish violet, or reddish brown shades can be made. Not in very wide use. The brown shades are known as Hatchett's or Florentine brown.

VEGETABLE VIOLET. Bright violet lake made from logwood. Very fugitive.

VELVET BROWN. See fawn brown.

VENETIAN RED. Originally a native earth containing 15 to 40% iron oxide, the present commercial material is artificially produced like the pure red oxides, but from 60 to 85% calcium sulphate is added during its manufacture. Although fairly satisfactory as a permanent colour, the calcium sulphate it contains is liable to cause trouble in oil, and for artists' use it is best replaced by artificial bright red oxide, which is purer, stronger, and brighter. A bluish shade of native iron oxide, comparable in hue to Indian red, is known as Spanish red. Venetian red is an average drier in oil, but produces a very hard and brittle film. See *Red Pigments*.

VENICE RED. Venetian red.

VERDEAZZURO. Malachite.

VERDERAME. Verdigris.

VERDET. Brilliant, dark green crystals of copper acetate; soluble in water; poisonous; formerly made in the south of France and used in water-colour painting. Permanence doubtful.

VERDETTA. Green earth.

VERDE VESSIE. Sap green.

VERDIGRIS. Hydrated copper acetate. Light, bluish green, permanent to light, but unreliable for painting. Reacts with some other pigments and is affected by them and by the atmosphere. Obsolete. Dates from Roman times; one of the early artificial pigments. Was still used to a limited extent during the nineteenth century.

VERMILION. Mercuric sulphide. A very opaque bright, pure red which works well in oil. It is the heaviest pigment in use. Erratically permanent, some grades are liable to turn black. This change is a reversion to a black form of mercuric sulphide, the cause of which is still a mystery after years of study. Best grades are made in England, France, and China. In oil painting it will not react with other permanent colours, including white lead. Recently largely supplanted by cadmium red. Vermilion was used in China at an early date. Earliest European date is about the eighth century; prior to that time, the inferior native ore, cinnabar, was used.

VERNALIS. Name given by the Society of Tempera Painters to a ceramic pigment formerly sold as Victoria green. Made by heating chalk and viridian. Permanent. Not ordinarily available.

VERNET GREEN. Bremen green.

VERONA BROWN. Burnt green earth. Transparent, but somewhat less so than green earth. Permanent and useful. Supplies of the dry colour vary in shade and are not always available.

VERONA GREEN. See green earth.

VERONESE GREEN. Because this term has been so loosely applied to emerald green, Verona green earth, viridian, and chrome green by tube colour manufacturers, it has little meaning. The colour of the usual material sold under this name resembles a rather pale viridian.

VERT ANTIQUE. Copper carbonate. Pale green. Permanent only if used alone and well bound in oil or varnish. Its principal use is for stippling over a brown undercoat to imitate the patine of copper and bronze, with which it is chemically identical.

VERT EMERAUDE. Viridian.

VESTORIAN BLUE. Egyptian blue.

VICTORIA GREEN. A mixture of 80 parts of viridian, 40 parts of zinc yellow, and 10 parts of barytes, gypsum, lithopone, or zinc oxide. The cheaper grades are likely to contain inferior colours and additional filler. The name is not a reliable designation. See vernalis and permanent green.

VIENNA BLUE. A variety of cobalt blue.

VIENNA GREEN. Mittis green.

VIENNA LAKE. Carmine.

VIENNA WHITE. Chalk made by air-slaking lime, as in the production of bianco sangiovanni. Used more as a polishing powder than as a pigment.

VINE BLACK. Made by calcining selected wood and other vegetable products. This pigment and the other blacks referred to it are members of a group of rather impure forms of carbon made by burning selected, but rather second-rate materials of vegetable, animal, and petroleum origins. They all have bluish undertones and when mixed with whites will produce blue-greys. They are inferior to the lampblack group in intensity and pigment properties. While these materials are probably permanent enough for most practical uses, it is wiser to select one of the purer forms of carbon as listed under *Black Pigments*. The vine black group should not be used in fresco or to mix with cement, mortar, etc., because of efflorescence from the water-soluble impurities which they always contain.

VIOLET CARMINE. A lake made from the colouring extracts of a tropical wood. Fairly clear, very reddish, transparent violet. Very fugitive, it first turns brown, then colourless.

VIOLET MADDER LAKE. Alizarin violet.

VIOLET ULTRAMARINE. Ultramarine violet.

VIRIDE AERIS. Verdigris.

VIRIDIAN. Hydrated chromium hydroxide. Very bright, clear, transparent, cool emerald shade; absolutely permanent except when roasted to more than a dull red heat, when it is converted into the anhydrous chromium oxide green. First made by Pannetier and Binet, Paris, 1838, as a secret product; introduced to artists, and the process first published by Guignet, Paris, 1859; available in England, 1862.

WELD. An obsolete yellow vegetable colour (luteolin) obtained from *Reseda luteola*.

WHITE EARTH. A pure white clay whose general composition and physical characteristics are the same as those of green earth. Not the same material as terra alba. It is highly absorbent to dyestuffs and therefore finds a limited use as a base for certain lakes.

WHITE LEAD. Basic lead carbonate. The best variety of corroded white lead is made by the so-called old Dutch process. A fine white colour; works well in oil, with which it forms a smooth unctuous mixture. Its defects are its poisonous action if taken internally and its property of turning brown when exposed to sulphur fumes. Very opaque; absorbs less oil than any other heavy white pigment. Suitable for artists' use only if well protected by oil, varnish, or overpainting; under these conditions it is absolutely permanent. It should not be used in other mediums. The best quality is not darkened by mixture in oil with other well-made permanent colours. In use since the prehistoric Greek period, second to Egyptian blue in the list of earliest artificial pigments, it was the only white oil colour widely available to artists until about the middle of the nineteenth century. Its use was not greatly diminished by substitution of newer whites until about 1910. See *White Pigments*.

WHITING. Native calcium carbonate, ground, washed, and refined. An inert pigment of considerable bulk, of use in oil painting only as an extender or adulterant. When ground in oil to a stiff paste, it does not retain its white or creamy-white colour, but the paste is yellowish brown and forms the familiar plastic cement known as putty. When used with aqueous mediums and glue sizes it retains its whiteness; it is valuable for such products as gesso, etc. The best grade is known as Paris white; the second best (usual paint store variety) is called 'Extra gilder's'; and a third grade, used mainly for putty, is called 'Commercial'. See chalk.

WINSOR BLUE. Phthalocyanine.

WOAD. Blue woad dyes were made from a plant which was cultivated in England from very early times, and the colour was used as a pigment to some extent until it was replaced by the more satisfactory indigo.

YEAST BLACK. See vine black.

YELLOW CARMINE. A yellow lake of vegetable origin; olive tone, transparent; very fugitive. See Dutch pink.

YELLOW LAKE. Transparent yellows from aniline dyes; some are very fugitive, others are semi-permanent. Made in a variety of shades; used principally in printing inks. Replaced by aureolin for artists' use.

YELLOW OXIDE OF IRON. Artificially produced by patented processes, this pigment is permanent for all uses except at high furnace temperatures, when it is likely to be converted into red oxide. It is made in a limited variety of shades corresponding to those of the natural ochres which it replaces, but it is always more brilliant than ochre, and has much greater tinting power.

YELLOW ULTRAMARINE. Ultramarine yellow. Also obsolete name for barium yellow.

ZAFFER OR ZAFFRE. Partially finished smalt; smalt in a stage before its final process.

ZINC CHROME. Zinc yellow.

ZINC GREEN. Cobalt green. Also a mixture of zinc yellow, Prussian blue (steel or Milori, not the reddish shades), and barytes.

ZINC OXIDE. Zinc white.

ZINC WHITE. Artists' name for pure zinc oxide. This material is used in painting because it does not have the two defects of flake white (it is not poisonous and it does not darken on exposure to sulphur fumes). It has much less hiding power than white lead, being only slightly better than semi-opaque. First made and sold in France toward the end of the eighteenth century; introduced commercially in America during the first quarter of the nineteenth century; successfully made in a large-scale industrial manner in 1845; began to be accepted as a general industrial pigment around 1860; but not very widely adopted by artists as an oil colour until the twentieth century. However, under the name of Chinese white it was almost immediately put into use as an artists' water colour; one English firm has had it on the market as a prepared water-colour white since 1834. See *White Pigments*.

ZINC YELLOW. Zinc chromate. A pale, semi-opaque yellow with a greenish tone. Permanent, but best grades are rare. Rather poisonous. Somewhat soluble in water; therefore generally considered to be not so good as barium and strontium yellows for artists' use. Some of the best and palest primrose shades contain much zinc oxide; few are the pure chromate. Introduced early in the nineteenth century. See *Yellow Pigments*.

ZINNOBER. Vermilion. When the term zinnober is applied to any other colour —for instance, to chrome green—it is being used merely as a fancy name for an inferior product.

ZIRCON WHITE. Zirconium oxide. Used to impart whiteness and opacity to ceramic glazes; not in use as a paint pigment.

Permanent Palettes for Various Techniques

Although any and all of the pigments in the following lists may be used, many will be found to be superfluous on a working palette. While a painter will naturally have his preferences for specific pigments, some pigments, although definitely separate colours with varying properties, are so closely related to each other that more than one will seldom be required in the same picture. These families or groups have here been printed on a single line. An asterisk(*) denotes little-used pigments of minor or occasional value.

PIGMENTS FOR OIL PAINTINGS

White. Zinc white.
Flake white. Cremnitz white.
Titanium oxide. Titanium pigment.

PIGMENTS FOR OIL PAINTINGS

Black.	Lampblack. Ivory black. Carbon black.
	Black oxide of iron (Mars black).
Red.	Cadmium, light.
	Alizarin red.
	Burnt sienna.
	Light red. Bright red oxide. Indian red. Mars red.
	*Cadmium, deep. Cadmium maroon.
Blue.	Ultramarine blue (all shades).
	True cobalt blue.
	Cerulean blue.
	Phthalocyanine (Monastral) blue.
Green.	Viridian.
	Chromium oxide.
	Phthalocyanine green.
	*Green earth.
	*Cobalt and turquoise greens.
	*Ultramarine green.
Yellow.	Cadmium, pale.
	Cadmium, medium. Cadmium, deep.
	Cadmium orange.
	Naples yellow.
	Mars yellow. Ochre. Transparent ochre. Raw sienna.
	Aureolin.
	Strontium yellow. Barium yellow.
Violet.	Alizarin violet. Cobalt violet. Manganese violet.
	Mars violet.
Brown.	Raw umber.
	Burnt umber.

Pigments such as green earth and ultramarine green, red, or violet, which have low tinctorial power, are valued more as glazing colours than as opaque body colours; several other permanent but very weak pigments have been omitted. The imitation cobalt blues and turquoise greens, which are special shades of ultramarine, are just as permanent and have the same physical properties as ultramarine blue.

Flake or Cremnitz white, Naples yellow, Prussian blue, and emerald green may be employed in permanent oil painting if special precautions are observed, as mentioned in the general list and in the remarks on the various pigments which follow this section.

Flake white and Naples yellow are best used in underpainting or well locked in from atmospheric action by varnish films. Cleanliness must be observed in handling them in order to prevent lead poisoning. When well-made lead pigments of high quality are used they may be freely mixed with the rest of the permanent palette; sulphur-bearing pigments, such as the cadmiums and ultramarine blue, will cause them to darken in oil mixtures only when poor or badly washed materials are used. Both flake white and

Naples yellow have such highly desirable characteristics that they are widely used despite their defects.

Emerald green, however, is a highly poisonous substance, and will turn black when mixed with any of several other pigments, when in contact with metals, and when exposed to the air, but it remains in limited use because its peculiar bright green cannot be easily duplicated by other pigments. When it must be used, it should be either painted full strength or tinted with titanium white, and well isolated from contact with the other pigments of the painting.

The pure iron oxide reds are referred to under *Red Pigments*. Indian red has a bluish or rose undertone, and Light red, a comparatively yellowish or salmon undertone. It is difficult to set down definite comments on these materials because of their confused nomenclature. In oil paints these two products should be used in preference to the native earth reds and also the artificial product, Venetian red, all of which are usually inferior. For the same reason vermilion, zinc yellow, vine black, and bone black, which are perhaps durable enough for the majority of uses, should not be used, since they can be replaced by more trustworthy pigments of equal colour value.

Pigments for Water Colour

None of the pigments which contain lead or other substances which are chemically affected by exposure to the atmosphere, may be used. Arrangement of the following list is the same as explained on page 68.

White. Chinese white.
Titanium oxide. Titanium pigment.

Black. Lampblack. Ivory black.
Mars black.

Red. Cadmium light.
Alizarin red.
Burnt sienna.
Pure iron oxides. (Indian red, Light red, Mars red.)
*Cadmium medium, deep, and maroon.

Yellow. Cadmium, pale.
Cadmium medium. Cadmium deep.
Cadmium orange.
Mars yellow. Ochre. Transparent ochre. Raw sienna.
Aureolin.
Strontium yellow. Barium yellow.

Blue. Ultramarine (all shades).
True cobalt blue.
Cerulean blue.
Phthalocyanine (Monastral) blue.

Green. Viridian.
Chromium oxide.

Green earth.
Phthalocyanine green.
*Cobalt, turquoise, and ultramarine greens.

Violet. Cobalt violet. Manganese violet.
Alizarin violet.
Mars violet.

Brown. Raw umber.
Burnt umber.
Alizarin brown.
*Verona brown (burnt green earth).

The weak or low tinctorial permanent colours, such as green earth, ultramarine ash, ultramarine violet, etc., are more useful in water colour than they are in oil, and some painters make continual use of them; but they are held to be unnecessary by the greater number of water-colour painters.

Prussian blue is still among the disputed or borderline water colours. In the past it has been more or less accepted as a necessary colour despite its doubtful permanence, which is discussed in greater detail under *Blue Pigments*. Because of the introduction of phthalocyanine blue, which is capable of approximating many of its effects in tints and mixtures, it has been omitted from the present list.

Some of the highest grades of Van Dyke brown are light-fast; these may be used in water-colour painting where the bad properties of this colour which cause its failures in oil have no significance.

Payne's grey, in the high-grade prepared water colours, is a permanent pigment valued as a useful and convenient colour by some painters, but considered unnecessary by others who prefer to make such mixtures on the palette.

For gouache (opaque or impasto water colour) the same palette is in use, but when used full strength the transparent pigments will function as body colours and exhibit their top tones. Their undertones will be brought out when they are mixed with a considerable amount of whites, but the colour effects of several will be different from those they exhibit in transparent water colour.

Cobalt violet usually contains arsenic and should be considered poisonous; some of the other chemical colours are not without harmful effect. In working with water colour one must not moisten brushes with the mouth.

Pigments for Tempera Painting

The list of pigments for tempera painting is the same as that for oil painting except that no white lead or other pigments containing lead may be used if the painting is to be completely tempera without oil or varnish glazes. When it is to be thoroughly varnished or glazed and varnished, flake white and Naples yellow may be used.

In most tempera mediums titanium has better brushing qualities than

either lead or zinc, and it displays none of the faults that it sometimes may exhibit in oil. The extremely powerful tinting strength of the pure oxide is sometimes awkward, and in most instances the barium composite variety will be preferable. The titanium pigments replace white lead in tempera more satisfactorily than they do in oil.

There are no chemical restrictions as to the various permanent colours which may or may not be used in underpaintings, as even when oil is a constituent of a correctly balanced emulsion, the variation in the flexibility of the films due to a variation in oil absorption by pigments is negligible. The remarks on colours for glazing oil paintings are applicable to colours for glazing tempera.

Pigments for Pastel

All the poisonous and the sulphur-sensitive pigments, such as Naples yellow, white lead, emerald green, etc., are eliminated from the pastel palette. When making one's own crayons only the strongest, highest grade colours should be selected, and in all tests particular attention should be paid to their bright appearance in the dry state. The only white usually necessary or desirable is precipitated chalk. French chalk (talc) has been recommended by some writers as an addition to pastel crayons on account of its peculiarly smooth or soapy texture. If it seems advisable for any reason to use one of the more opaque or heavy whites, no more than a 10% addition of titanium to the chalk should be used.

Some pigments, such as zinc yellow, which are often rejected for use in other mediums on account of their slight solubility in water, may be used in pastel where this property is of no importance; also some of the colours which bleed in oil can be employed if thoroughly light-proof. This makes many of the newer coal tar products available. Some of the best grades of Van Dyke brown are light-proof and have permanence in pastel in spite of their bad behaviour in oil. Some of the borderline colours have been recommended on the theory that the relative thickness of the pastel coating and the absence of medium reduce the likelihood of failure to a minimum, but as in any other technique it is safest to use only the most light-proof pigments.

Full strength Prussian blue has an undesirable bronzy sheen, and its diluted, very pale tones are not safe. However, most objections to the use of Prussian blue in pastel are based on theoretical or laboratory standards. It was freely used in European and early American pastel portraits, especially in backgrounds and draperies, where it has survived without any change. It is doubtful whether any artist who has specialized in pastel has ever excluded it, except in very pale tones.

With the exception of the poisonous and sulphur-sensitive pigments, all the permanent oil, water colour, and tempera colours can be used, but, as in gouache, the transparent or glaze pigments will function as body colours. Emerald green, all the lead colours, and cobalt violet are considered too poisonous because of the dusting of the crayons during use.

Pigments for Fresco Painting

Remarks have been made elsewhere as to the lack of modern scientific and technical studies directly relating to artists' materials; much carefully controlled research remains to be done to bring our data on fresco colours up to date.

The fresco palette is more restricted than any of the others; the pigments must not only be of absolute permanence to light, but must resist the alkaline action of the lime plaster and the acid action of polluted air. Pigments must be free from soluble salts and any impurities that are likely to react with acids or alkalis. When selecting pigments, attention should be given to the brilliance and purity of tone in the dry state, which is approximately if not exactly the same as the finished fresco effect. Notes on the further refinement of impure pigments will be found on page 96.

EGYPTIAN MURAL PALETTE[26]

Black.	Carbon (lampblack).
Blue.	Azurite and Egyptian blue frit.
Brown.	Various native earths.
Green.	Malachite and crysocolla.
Red.	Native red oxides.
White.	Chalk and gypsum.
Yellow.	Ochre and native orpiment.

MINOAN FRESCO PALETTE[21]

White.	Lime putty.
Black.	Powdered slate.
Red.	Native red oxide.
Blue	Egyptian blue frit.
Green.	Mixtures of blue, black, and yellow.
Yellow.	Ochre.

ROMAN FRESCO PALETTE[2]

Black.	Lampblack, possibly also bone black.
Blue.	Egyptian blue, possibly copper ores.
Brown.	Native earths.
Green.	Egyptian green, green earth.
White.	Lime.
Yellow.	Ochres.
Red.	Native oxides, Pozzuoli red, etc.

Probably refined, washed, and burnt earths were used. The method of making Egyptian blue and green was brought from Egypt.

TRADITIONAL ITALIAN FRESCO PALETTE

White. Bianco sangiovanni.
Black. Lampblack.
Red. Native Venetian red or Spanish red. Pozzuoli red and other native red oxides.
Burnt sienna.
Vermilion applied *secco*.
Blue. Egyptian blue. Azurite. Smalt.
Native ultramarine applied *secco*.
Green. Green earth.
Mixtures of blue and yellow.
Yellow. Ochre. Raw sienna.
Brown. Raw umber.
Burnt umber.
Verona brown.

Refined, washed, and burnt native oxides and ochres were well known.

MODERN FRESCO PALETTE

White. Slaked lime putty.
Bianco sangiovanni.
Neutral blanc fixe.
Black. Mars black.
Lampblack.
Red. Several shades of pure artificial red oxides: Mars red, Indian red, Light red, etc.
Burnt sienna.
Blue. True cobalt blue.
Cerulean blue.
Green. Viridian.
Chromium oxide.
Cobalt green.
Green earth.
Yellow. Mars yellow. French ochre. Italian raw sienna.
Violet. Cobalt violet.
Mars violet.
Brown. Raw Turkey umber.
Burnt Turkey umber.
Verona brown.

SELECTED FRESCO PALETTE FOR PERMANENT FRESCOES

As noted in the section on *Fresco Painting*, this palette is suggested as being especially resistant to the corrosive action of polluted air. All the pigments must be neutral, free from soluble salts and other impurities.

White.	Blanc fixe.
Black.	Mars black.
Red.	Indian red. Light red.
Blue.	Cobalt blue. Cerulean blue.
Green.	Chromium oxide. Viridian.
Yellow.	Mars yellow.
Violet.	Mars violet.

Many colours not universally adopted or at present disputed, such as the cadmium lithopones, phthalocyanine blue, Hansa yellow lakes, and aureolin, have been proposed as fresco colours. Some have shown promise in tests but, so far, data have been insufficient to form the bases for definite opinions. Painters who add lime or limewater to their colours favour pure slaked lime as a white; those who depend solely on the capillary penetration of their pigments into the surface of the wall prefer a more inert, non-binding white. It is doubtful whether the Pozzuoli red mentioned by some writers is always the authentic cementitious material; its colour, however, is usually a highly desirable rosy shade of red. As remarked under *Fresco Painting*, the cementing property of this substance is of doubtful or negative value. A number of perfectly suitable fresco colours, such as true turquoise green, potter's pink, and manganese violet, are not ordinarily available on the British and American market. The cadmiums have been generally rejected for three reasons: there is doubt as to their permanent resistance to the alkaline lime, their colour effects in the dry state are very brilliant and usually out of key with the rest of the fresco palette, and they are all sulphides and therefore among those compounds most sensitive to disintegration by minute amounts of mineral acids in the air. The cobalt violets now on the market vary considerably in colour and chemical properties and some which are light-proof in other mediums will fade when exposed in contact with lime; untried specimens should be tested under fresco conditions before adoption. Colours sold for enamelling and other ceramic uses have bad paint-pigment properties and always contain added fluxing and refractory ingredients.

Properties of Pigments in Common Use

The following section includes further details on the properties and uses of pigments; comparisons and data on matching colours, substitutions for undesirable, obsolete, or rare pigments. Pigments are arranged by colour.

Matching Colours. While in most cases an approximate match for a specific colour may be made by using a mixture of a composition different from that of the original paint, and while such mixtures may be entirely adequate for the actual application in view, a study of colour theory reveals the difficulty of securing precise, accurate effects unless the proper pigment is employed. The variation in physical and optical properties of pigments of varying chemical or physical structure will result in differences, even when a general similarity of colour, shade, or tone seems apparent.

In general, mixtures of two colours are invariably duller or less clear than single pigments of good quality; the addition of a third colour is accompanied by a further reduction in clarity. However, we do not ordinarily paint with pure or raw colour, but usually depend upon mixed or broken tones for our effects; control of their effectiveness can be attained only by experience and a knowledge of the behaviour of the various individual pigments in mixtures. The statement that the presence of fillers or inert materials, as in students' grade or other cheap colours, does not alter their properties for pictorial or decorative effects, is not quite accurate; a pure colour has more clarity of tone and will give superior effects all around.

The exact matches required in careful restorations, in alterations, and in additions to finished works, require careful, precise mixing and sometimes a viewing in bright, direct sunlight—procedures seldom called for in the practice of creative painting.

Blue Pigments

Ultramarine is the standard blue colour in artistic use. The best quality ultramarines as made since 1826 are identical with the native lapis lazuli for all practical purposes. They have the same chemical reactions and are distinguishable from it only upon microscopic examination, when the difference in crystalline structure is immediately apparent. The principal defect to be taken into account in the use of ultramarine is its extreme susceptibility to bleaching by even minute amounts of mineral acids; hence it has never been used in the fresco palette. Like most other high-temperature furnace products it is otherwise of great permanence. When ground in oil, ultramarine normally has one of the worst painting consistencies of any of the pigments and tends to make paints of erratic and usually stringy nature; it is therefore much diluted with waxes and other stabilizers by some makers of tube colours who require all their paints to have the same buttery plasticity. Artists who grind their own oil colours find, however, that they are able to paint with colours which are not quite up to this standard. Furthermore, ultramarine in oil is of a hue which is seldom employed full strength; it is almost always used as a tinting colour in admixture with whites, yellows, etc., which tend to impart a normal consistency to the mixtures.

True cobalt blue (Thénard's blue) is one of the more expensive colours and in cheaper paints it is universally replaced by a cobalt shade of ultramarine. This imitation is satisfactory for many practical painting purposes and need give the artist no concern, as it is as reliably permanent a pigment as can be desired except in the case of fresco painting, where the genuine Thénard's blue must be insisted upon because of the previously mentioned effect of atmospheric acid on the colour of the imitation cobalt. The colour of the imitation or ultramarine cobalt, however, is never an exact match for the true cobalt blue, especially in undertone; it is an approximation rather than a close match. The pigment listed as cobalt ultramarine (Gahn's blue)

is not always available and its name may be used to designate ordinary imitation cobalt blue.

Prussian blue is the most disputed member of the blue group as regards permanence; it might be placed in a class by itself, as a borderline pigment. Its colour is unlike that of the other blues; it is particularly useful in mixtures. For the past seventy-five years or so it has been alternately approved and condemned. There is a great difference in clarity and beauty of colour as well as in permanence between the common varieties of Prussian blue and the very best, well-washed grades, such as the pure Chinese and Milori blues. Some samples will eventually turn brownish when used in oil, or will fade out appreciably when used in thin layers or in extremely weak tints with zinc white in water colour and tempera. Prussian blue is destroyed by alkalis and therefore cannot be used in fresco.

Laurie[34] recognizes it as a borderline colour; he is of the opinion that the practical evidence is in its favour as a reliably permanent colour in oil, but that because it is transparent, absorbs much oil, and will not mask the yellowing of oil, it should be used only in thin glazes and as a tinting colour with much white, in contradiction to the foregoing statement which is based on some laboratory evidence. He believes it should not be used in water colour. Ostwald[29] recommends its use as a nearly indispensable colour, especially in pastel, where he says that conditions which affect it in oil and place it in the borderline class are not present. Doerner[38] declares that it is permanent in all techniques except fresco but warns against its lavish use in oil paintings on optical grounds (it gives the painting a lower key than when ultramarine or cobalt is used); he also mentions a tendency for it to fade when mixed with large amounts of zinc white and exposed to light, recovering its colour again in the dark.

The variation in quality of Prussian blue from various sources accounts for some of its variable behaviour as observed by these investigators; another factor, no doubt, is the variation in methods of testing and the different standards used. A Prussian blue will fade or become discoloured when it is exposed to a moist atmosphere or outdoor conditions over a period of time; the same specimen may survive indefinitely when exposed to normal indoor conditions such as those under which works of art are usually preserved. The modern consensus of opinion is that it is best avoided, but that when a painter believes he needs it to obtain desired colour effects, he is justified in risking its occasional sparing use in middle tones and mixed colours. It will seldom be desired in full strength because the better grades have a pronounced bronze. In fresco or any other alkaline substance it would fail immediately. Personally I do not hesitate to use it in any kind of opaque painting but avoid its use in thin, transparent glazes and washes. Although its particle formation is extremely fine, when ground in oil it tends to agglomerate and form somewhat granular pastes; this is less marked in the better grades. In mixtures of dark colours—greens, olives, brown, etc.—it has the property of making rather deep, full toned shades, less dead or chalky than those of the other blues. There is no exact substitute for the shades it produces in mixtures,

and mixed pigments such as the chrome greens and Hooker's green can scarcely be duplicated without its use. Phthalocyanine blue, as noted below, comes nearest to being a substitute.

With the exception of cerulean blue, the blue pigments have many properties in common. They all have a transparent, or semi-transparent, deep, dark hue when ground in oil, they absorb much oil, and they do not produce pastes of desirable plasticity. Cerulean blue has greater opacity or hiding power than the other blues. Its full-strength shade is a rather pale sky-blue with a greenish tone. It is a very good drier and its general pigment properties are good. It has been considered low in oil absorption, and so it is, on a basis of weight, but the current prevailing grade shows a very high oil index by volume (see page 117). Because it is one of the more expensive pigments, never employed in industrial paints but only produced in small quantities for artistic and ceramic use, the cheaper and less reputable brands are likely to contain either imitations, or weak mixtures of the true material with extenders or inert substances.

Phthalocyanine (Monastral) blue has proved an interesting addition to oil, water colour, and tempera palettes; some of its mixtures can substitute very well for those of Prussian blue. Both Prussian and phthalocyanine blues have so much greater tinting power than the average pigment that they can be more conveniently used when they have been made with inert pigments such as blanc fixe or alumina hydrate. This reduction will also benefit the colour in other respects. It eliminates or reduces the bronzy or coppery sheen, and improves general structural or pigment properties, which are not particularly good in either of these materials.

Green Pigments

If it becomes necessary to secure an exact match for a green paint, it will be found that the greens are very difficult to duplicate by the use of materials other than those identical with the ones which composed the original paint. Greens are toned down or brought toward the olive, if too brilliant, by the addition of a clear red or reddish pigment, burnt sienna for the warmer shades, cadmium red or alizarin for the cooler ones. The character of a mixed green made with a lemon or pale yellow is totally different from that of one made with a golden (medium or deep) yellow.

Chrome greens are universally taboo in artistic painting; their colour stability is less than that of either of their single ingredients; usually the Prussian blue fades first; the green becomes yellowish or brownish and then lighter as the chrome yellow changes. Chrome greens are quite difficult to match exactly with permanent pigments without the use of Prussian blue.

Emerald green is most nearly approximated by mixtures of viridian, strontium yellow, and white, but the pure or strong shades cannot be exactly duplicated by mixtures of other inorganic pigments. This is the sole reason for the survival of this dangerous pigment. When painters had no viridian those who realized the reactive nature of emerald green were careful to lock

it in well with varnish and isolate it from contact with other pigments; the work of those who used it freely has suffered greatly with age, as mentioned under *Brown Pigments.*

Sap greens resemble mixtures of Prussian blue and transparent ochre, or Prussian blue and aureolin dulled with a touch of burnt sienna.

Hooker's green may be matched by a mixture of Prussian blue and aureolin. Most greens made with Prussian blue cannot be duplicated without its use, but a mixture of Prussian blue and a permanent yellow is far preferable to one in which such definitely fugitive yellow pigments as gamboge, lakes from buckthorn berries, etc., are used. Phthalocyanine blue is of some value for producing new green shades and for approximating the tones of the older greens.

Verdigris and similar copper greens are rather easily imitated by using viridian as a starting point. The great variety of shades in which these colours were made make it impractical to mention the additional pigments specifically.

Chromium oxide green is one of the most inert and permanent pigments in use, but it finds a smaller application in artistic painting than do other greens on account of its low tinctorial power and its limited colour effect.

Viridian, which is equally durable for all artistic and industrial pigment purposes, except in high temperature work, is a valuable artists' colour. The inferior grades sometimes contain impurities in the form of complex mixtures of chromates and borates; while these are water-soluble, they are quite difficult for the manufacturers to wash out. Their presence is highly undesirable, and therefore only viridian of the highest quality should be used. The best American dry colour is usually cleaner and cooler in shade than the European product, which, by comparison, tends toward yellowish or muddy tones; it should, therefore, be preferred by fresco painters. When viewed under the microscope, viridian resembles small broken fragments of emeralds. Its colour effect when used in transparent films is just this brilliant transparent green, but when it is used full strength in thick pasty layers it will exhibit a duller, more blackish body colour or mass tone because of the building up of a thick layer of pigment particles which impede and absorb the transmitted light rays, thus producing an opaque coating.

Phthalocyanine green is a more intense clear tinting colour than viridian, and will produce different shades in mixtures with other pigments.

Mixtures of burnt sienna with Prussian blue, sometimes toned with yellows, supplied many clear olive and sea green hues in older paintings.

Red Pigments

The wide range of effects which may easily be obtained with the permanent reds and mixtures of them makes it simple to match reds or reddish colours. For nearly all purposes, vermilion is perfectly replaced by the light cadmium reds; if these are too cold or chalky in comparison with it, a touch of whatever toning colour may be necessary is added. Alizarin will substitute for all the obsolete transparent lakes. The brilliant geranium, magenta, rose

pink, and similar colours have never been widely accepted in artistic painting or considered to be necessary hues. Permanent ones could be made at present.

The earth reds (Venetian red, etc.) should be replaced whenever possible by their artificial counterparts, the Mars colours and the bright red oxides. Except in fresco painting, however, this is not a seriously important precaution; and it is fortunate, since the nomenclature for these colours at present is such as to bewilder persons not thoroughly familiar with their properties.

In the colour trade the impure native oxide of bluish tone is known mainly as Spanish red, and the scarlet shade as Venetian red. The pure varieties are called Indian red (bluish shade) and Light red or bright red oxide. However, special trade names or numbers for various grades are widely used in the paint industry, thereby eliminating much of the confusion.

The principal distinction to be made is that one branch of the family, of which Indian red is typical, has a deep bluish tone, and when reduced with white produces rose pinks; the other branch, of which Light red is typical, is brighter and more scarlet in mass tone, and when reduced with white produces salmon pinks. Mars violets and highly burned Indian reds produce lavenders when reduced with white.

Some makers of artists' materials have attempted to simplify the confusion in nomenclature by calling all the pure, artificial red oxides Mars red or Mars scarlet, maroon, etc., reserving the older meaningless names for the native or impure oxides; for the Mars colours are all artificial iron oxides of great permanence, some of them varying only slightly in colour, composition, and method of manufacture from the pure Indian red and Light red or bright red oxides.

The ancient and medieval crimson lakes had animal or vegetable origins: kermes, grain, madder, dragon's blood, Brazil wood, and, later, cochineal or carmine. Alizarin replaces all of them, sometimes with a small amount of dulling or toning if exact matches are required. None of these older red lakes was used for any special quality it may have shown in comparison with another; the optimum was considered to be a transparent ruby or blood red which produced a pure rose pink when diluted with white; the most brilliant, most reliable, and most available one was selected.

Although inferior grades are common, alizarin reds have, for the past twenty years or so, been made in a superlative quality which is permanent under conditions that cause older or inferior varieties to fail. The highest grade product has a brilliant rosy tone in the dry state; it is perfectly clear and transparent, will not liver with pure oils, and may be freely mixed with earth colours. Alumina hydrate is employed in its manufacture, but in a small proportion and as much for its chemical function as for its use as a base or inert material, so that the best grades are almost toners, compared with the usual lake colour. Alizarin reds and violets are the only organic red pigments universally accepted for permanent easel painting.

The manufacture of a perfect alizarin requires great skill on the part of

the colourmaker. One of several important points is that while it is being made the material must be kept absolutely free from the contamination of iron, which destroys its character. This is probably the reason so many writers go to such extremes to warn painters against its admixture with and even its overpainting upon earth colours that contain iron. I find that with a best-grade alizarin such warnings are unnecessary, for in its finished state it is not sensitive to iron to an extent that would make these procedures dangerous. According to tests, it can be freely mixed with any of the other approved pigments without bad effect. Alizarin is not of absolute fastness to light in the same sense in which the inorganic colours are light-fast. It can be broken down under accelerated tests; however, it is adequately permanent for use under normal conditions of all accepted artistic painting techniques except fresco.

Alizarin comes in the form of an extremely fluffy, light-weight powder, one pound of which will almost fill a half-gallon can. A pound of vermilion will go into a four-ounce jar. Both vermilion and alizarin happen to be substances which repel water to such an extent that they are difficult to mix into aqueous mediums, especially when one attempts to stir them into the medium in a container. A round rod should be used for this purpose instead of a flat palette knife. With a little patience, they will mix in. Colours which repel either oil or water will go into suspension more easily on a slab, under a muller or spatula. If alcohol be used to start the wetting with oil, only the anhydrous grade should be employed, and it should be well mulled or the mixture allowed to remain on the slab long enough for the alcohol to evaporate.

The true madder root lakes made by the older process, especially those of good quality, are now very rarely found on the market. They can be obtained from only the most reliable sources.

Yellow Pigments

Chrome yellows and oranges are perfectly replaced by the cadmiums for all artists' purposes. Formerly there was some doubt as to the light-proof qualities of some cadmium shades, especially the palest yellows, but I find that all the modern cadmium-barium yellows are of equal permanence under severe accelerated test conditions and are entirely suitable for permanent artistic painting. They may have less tinctorial power than some of the older pure sulphide yellows but they are acceptably strong and compare favourably with the average artists' colour in this respect. Most specimens are finely divided and soft, and work well in oil. The term cadmium lithopone does not mean that the colour has any of the undesirable features of lithopone white, but merely refers to its method of manufacture in order to distinguish it from the pure sulphide pigments.

Aureolin, sometimes toned with another colour, will replace the obsolete transparent yellows—gamboge, Indian yellow, etc. The modern light-proof yellow lakes such as Hansa yellow are permanent under the most severe

laboratory tests. Mars yellow can serve as a starting point to duplicate most of the ochres and raw siennas if desired, but it should be considered an addition to this family of colours rather than a substitute for any of them.

The use of the European term transparent gold ochre by some makers of oil colours to describe an ochre which contains a large percentage of transparent material is unfortunate, as the term golden ochre has long been employed in the English and American colour trade to describe an inferior product containing chrome yellow. The best transparent ochre is refined from a rather scarce native ore which contains a smaller percentage of iron than the average; other grades (which are perhaps just as desirable) may be made by mixing alumina hydrate with a deep-toned native ochre. The colour is a useful one and it is doubtful whether its great transparency and high inert pigment content will promote change in tone because of yellowing of the oil, as its hue is very close to that of a rather deep-coloured oil. Because of the industrial unimportance and limited production of this native transparent ochre, the material sold as a dry colour is likely to be the chrome mixture.

The family of light, rather greenish yellows—zinc, strontium, and barium yellows—is not among the most useful groups of pigments, but its colours can be employed to advantage when very pale, clear tones are required or when further variety of greens is needed. Strontium yellow is the best of this group; barium yellow is very weak and pale; and the usual grade of zinc yellow is so apt to become greenish that it has been omitted from the permanent lists in this book.

Naples yellow seems to have been the most disputed yellow colour among nineteenth-century painters and commentators; some claimed that it was indispensable and others that its colour might easily be duplicated by such mixtures as zinc oxide, transparent ochre, and pale cadmium yellow. The true product, lead antimoniate, was for a period somewhat unstandardized; it was even claimed that no such pigment had ever been in general use and that any pigment combination of similar superficial hue or top tone could be sold under its label. This was because it never has had any industrial significance, and has never been made in other than small quantities as an artists' colour and for ceramic use. The precautions for the use of lead-bearing pigments apply to it; it has the same defects as white lead. True Naples yellow in oil has the peculiar property of turning a muddy green when the paste is rubbed with a steel palette knife. The modern product does not alter to any appreciable degree when a clean polished blade is used to gather and pick up the paste, but for rubbing and working it thoroughly only the glass muller or a spatula with a blade made of stainless steel, hard rubber or horn should be used.

Genuine Naples yellow is produced commercially in limited amounts in about six shades, from a greenish yellow to a comparatively pinkish orange yellow. These shades are not very widely different, and the usual material available on the market as a dry colour seldom offers a choice of more than two shades, generally called light and dark. Because of its permanence to light and the general all-round excellence of its pigment properties, which closely resemble those of flake white, Naples yellow is well liked by painters.

Ochres occur in all parts of the world, but the finest ones, in fact the only ones suitable for artistic colours, are mined in France, where they are most carefully washed, refined, and placed on the market as recognized uniform grades designated by a series of letters established by long use. For example, one of the most desirable ochres is called J.F.L.S. which stands for *jaune, fin, lavé, surfin*. Each earth pigment is produced in its highest grade in one particular locality; other varieties are sometimes recommended as being also suitable, but in every case this is done for reasons other than the single aim to secure the finest grade material. Mars yellow is much more brilliant and powerful than the ochres and raw siennas; theoretically it should supplant them, especially because of its purity, but artists often prefer the more delicate and subtle tones of the native earths.

Brown Pigments

Van Dyke brown was employed not so much for its general brown hue, which can easily be matched by a mixture of black, red oxide, and a little ochre or sienna, as for its rich, deep tones (either by itself or in mixtures) against which the umbers seem pale and chalky. Emerald green is another pigment which produces non-chalky mixtures; and rich, deep, brownish shades (ranging from an olive or greenish brown to a warm black) were often produced by a mixture of the two. Old oil paintings in which such mixtures were employed are usually found to be deteriorated into a mass of wide traction fissures. Because neither of these pigments is now approved for use in oil paint, these brownish mixtures are approximately matched by employing the least chalky of the more permanent pigments such as burnt sienna and Prussian blue. Despite the doubtful value of Prussian blue, this mixture is safer than the other. A touch of cadmium orange or red may also be found useful. Burnt sienna is one of the most valuable colours for producing mixed or broken hues of depth and clarity. Like other earths, it is sold in a great variety of top tones, but the undertones are fairly uniform. The deepest and darkest shades are the most useful. Sometimes it is classified as a brown, and sometimes as a red.

Raw and burnt umbers are the most widely used browns; they have a pronounced siccative effect on oil, and tend to produce tough, flexible, leathery films. Their oil content is so high that when used full strength in undercoats they have a tendency to produce cracking of the top coat, as noted in the section on oil painting. To be on the safe side, they should not be used in underpaintings in greater concentration than a 40% admixture with pigments of low or medium oil absorption; up to this amount they may be added to undercoats in order to secure quick drying and uniform, durable paint films.

Sepia and bistre, used exclusively in water colours and wash drawings, are not so commonly employed as they were in the past. Sepia is rated as a semi-permanent or borderline colour, bistre as definitely not permanent. Sepia was valued for its versatility in producing water-colour washes of great

variation in tone or 'colour', depending on its dilution with water; therefore, in the case of a substitute colour used to replace one of its hues, a diluted or more highly concentrated mixture will not necessarily match the diluted or more highly concentrated original. Bistre is a rather cool, greenish colour compared with sepia; the difference between them is analogous to that between raw and burnt umbers, but their tones are more subtle and delicate than those of the umbers.

Violet or Purple Pigments

The use of violet pigments in painting is generally limited; many painters prefer the broken violets produced by mixtures of blues and reds, because they fall into the average colour scheme better than the pure, clear violet pigments which, as a rule, tend to produce cold or harsh effects. When a bright, clean violet colour is desired, cobalt violet is usually found suitable by most painters. A more brilliant, intense, clear, transparent colour is the modern alizarin or madder violet, which does not seem to be ground in prepared oil or water colours by many makers, perhaps because manufacturers are loath to add any further items to their already top-heavy lists. Compared with the bright cobalt and alizarin violets, Mars violet is dull and subdued, but when used straight or in mixtures on the average picture it serves well to produce the majority of purple and violet colours ordinarily required.

Black Pigments

The common black pigments—ivory, bone, lamp, vine, and drop black—all consist of carbon obtained in the form of soot by burning various materials. They are very fluffy and of low specific gravity—25 pounds of some grades will fill a sugar barrel; the same barrel will often hold 300 pounds of a pigment of average density. They absorb a considerable amount of oil in terms of weight; however, when computed by volume it is not so much as the weight figures indicate. The carbon blacks are all very poor driers in oil and will retard the drying of a normal film unless mixed with a siccative pigment, such as umber. The soluble salts in the impure members of this group (and in some of the purer ones also) will effloresce when the pigment is used as a mortar colour or in fresco; also the fluffy and water-repelling nature of this group makes them less desirable than mineral blacks for most water medium uses. The material specifically called carbon black is the most intense in colour and tinctorial power of any of this family, but it is not widely used as an artists' pigment because of other faults, as noted.

The non-mineral blacks may be grouped as follows:

Pure Carbon

Carbon black, lampblack.

Impure Carbon

Animal sources: ivory black, bone black.

Vegetable sources: vine black, charcoal black.

BLACK PIGMENTS

Frankfort or drop black is made from a great variety of vegetable and animal materials. From the manufacturer's point of view the difference between lampblack and carbon black is that lampblack is soot or carbon collected by the smudge process, and carbon black is made by direct contact of the flame with a metal plate. The inferior grades of lampblack contain small amounts of greasy materials.

Ivory black is the only member of the impure carbon group that is recommended as a permanent artists' colour. It is one of the worst materials to use full strength or nearly full strength as an undercoat in oil painting: a film of any other pigment laid over straight ivory black is extremely likely to crack.

The grays obtained by mixing Mars black with white lead or zinc white are bluish, but they seem brownish in comparison with the cooler grays obtained by mixing whites with the carbon black group.

Black iron oxide or Mars black is a thoroughly trustworthy pigment. Its introduction to the artists' palette is rather recent. The native magnetic oxide and the blacks made of ground shale or slate are too coarse for average pigment use, but they are used industrially to some extent in water pastes as mortar colours, etc.

Black or blackish effects produced by mixtures of other colours are mentioned under *Brown Pigments*. Very exact matching of blacks requires the direct rays of sunlight rather than diffused north light.

WHITE PIGMENTS

The usual classification of white pigments includes several of the materials grouped separately in this book under the heading of *Inert Pigments*. Under the present heading only those pigments which retain their colour and opacity when ground in oil are listed.

White lead is one of the earliest artificially manufactured pigments recorded; it was employed in China as far back as we have any history of the materials of Chinese painting, and was used in the earliest periods of European civilization. It has very desirable properties when ground in oil: it has the lowest oil absorption of all white pigments, it unites with oil to form a buttery paste which has fine brushing qualities, and it is noted for its opacity or hiding power and its pleasing tonal characteristics. It produces paint films of great durability. Its two defects are its toxic nature (see *Lead Poisoning*) and the fact that the surface of white lead paint films is liable to turn dark brown when acted upon by air which is polluted with sulphur fumes. The latter defect is of slight consequence in oil paintings, where the pigment is usually well protected and locked in by oils and varnishes, or in varnished tempera paintings, or in undercoats; but it definitely precludes the use of white lead in all the other artistic painting mediums. Anyway, white lead brushes out poorly in most water mediums. Should an oil painting be affected by sulphur as described above, the remedy is quite simple; it is mentioned on page 345. However, the only conditions under which this darkening would be

at all likely to occur would be such as are found in kitchens, stables, industrial or factory buildings, and outdoors in localities where soft coal is burned. Artistic oil paintings are not usually exposed to such conditions. Under the conditions which prevail in easel painting, the best white leads will not react with any of the approved permanent pigments, even those which contain combined sulphur, provided these are of high quality.

The best grade of white lead is usually known to artists as flake white, a corroded basic lead carbonate made by what is known as the old Dutch process, though essentially this process is the same as that described by Theophrastus and used in ancient Rome and Greece. The number of modern lead compounds made and used industrially under the name of white lead is large; many of them are superior to flake white in one or two painting properties or in ease and economy of manufacture. Cremnitz white, a nineteenth-century development, is made by a modification of the process, which allows it to be more carefully controlled; it is a somewhat purer, more brilliant white, but it has less opacity. Various authorities rate one slightly above the other; for artists' use both are superior to the rest of the industrial white lead pigments. The basic raw material of Dutch process or flake white is metallic lead; that of Cremnitz white is litharge.

It is doubtful whether any manufacturers of prepared artists' oil colours make a distinction between the various kinds of white lead; fortunately, the differences are small enough so that if a pure basic lead carbonate with the best pigment properties is selected, the product will be satisfactory. Much white lead in oil is made by blending more than one variety.

White lead has always been the basis or principal pigment for oil painting. Its properties in oil, as regards grinding, drying, brushing, and other manipulations, its opacity, flexibility, and durability are so superior to those of other whites and, in fact, most other pigments, that it is not only a standard of comparison by which the physical properties of other pigments are judged, but it is beyond some of the rules and restrictions which govern the correct application of colours. Old portraits which have been thinly painted except in the faces, where a heavier coat of paint consisting principally of white lead has been used, are often found to have disintegrated except for the faces, which are in perfect condition; and it is not uncommon to find other old paintings in which white lead areas, thin or thick, have outlived both impasto and very thin coats of other colours.

The success of the oil painting technique as a standard easel painting process for several hundred years has been based largely upon the use of this pigment, and its exclusion from many latter-day palettes has resulted in a lowering of some of the good qualities of the technique. Because of these points and because none of our other whites is entirely perfect in oil, flake white still remains in use as a pigment for oil painting, despite the claims of zinc and titanium whites.

Zinc white is a term peculiar to the artists' material trade, where it is intended to describe zinc oxide of the highest degree of purity. The manufacture and sale of artists' colours is an insignificant branch of the colour

industry. Other white pigments, such as lithopone, contain zinc, and could, in view of the disorganized system of nomenclature, be sold as zinc white. The best grades of domestic dry zinc oxide are sold under the trade name of Florence French Process zinc oxides. There are three varieties, all of which are more than 99% pure and any one of which may be employed, as the differences between them are not great. White Seal is the finest-grained and the fluffiest; Green Seal is just as white but denser and less bulky; Red Seal is slightly inferior in whiteness and fineness of grain to the others. A grade of still higher chemical purity is also available under the name of B.P. zinc oxide, but this is made for pharmaceutical preparations and has inferior paint pigment or physical qualities. White Seal is generally considered best suited for artists' paints.

Zinc white as a paint pigment is free from the two defects of the white leads. It is not a dangerous poison, and since zinc sulphide is white, any action that sulphur fumes might have on zinc oxide in a painting will not alter its colour. Compared with white lead as an oil colour, it has a harsher, colder, or bluer effect, and is very much less opaque. It is employed in oil where its lack of great opacity is either desirable or of no detriment; if a more opaque white is required, white lead or a mixture of 50% titanium with zinc oxide may be used.

Zinc white is a reactive pigment in oil (see page 118), and unites with it but not in the same way as flake white does. It tends to make brittle, hard films in comparison with the tough, flexible films of white lead. Its film has none of the desirable paint qualities described under flake white, it does not brush out so well, and it is an exceptionally bad drier. Its particle structure is rather finer than that of the average pigment. Poppy oil films are definitely less permanent with zinc than with flake white.

Under severe weathering conditions such as those to which outside house paints are subjected (and which may be taken, in a measure, as accelerated or exaggerated indications of the conditions an artistic painting may undergo over a long period of years) white lead films decay by becoming soft and powdery, zinc films by becoming brittle, cracking and flaking; in the average climate, mixtures of the two, containing not more than 60% of either, are more resistant to decay than is zinc or lead alone. An addition of 10% of blanc fixe increases the durability of such outdoor paints, evidently by reinforcing the structural strength of the film.

Although zinc oxide is a very slow drier in linseed oil, and remains rather soft and flexible for some time, the oxidation of the oil is merely retarded; the drying action will continue until the film has reached its characteristic hard, brittle condition. Hence, zinc oxide is not so good a material as flake or Cremnitz white for use in underpaintings; it is liable to be the cause of cracking on account of the shrinkage in volume accompanying the slow drying of the film. This danger is increased by its finely divided particle size and it is more likely to take place when poppy oil is used. In general, zinc white, especially when ground in poppy oil, may be considered of greatest value as a top coat, or in simple, direct, one-sitting painting. Oil grounds made with zinc oxide should be aged for at least six months before use.

In all aqueous mediums zinc white is free from defects and gives very good results. It has long been used as a water colour under the name of Chinese white, and when thus employed its opacity is usually satisfactory. Where it has not sufficient hiding power, as in work done for photographic reproduction, titanium should be substituted for it.

Lithopone is used for interior wall paints, in enormous quantities, but despite the modern improvements made in its properties, it is universally condemned as an artists' white. In oil paints it is considerably inferior in colour and colour stability to zinc oxide. However, it has good opacity, and its structural or film-forming properties are excellent; therefore it is generally considered acceptable for use in grounds, either in water or oil mixtures. Its fineness of grain may cause trouble when used with poppy oil. Lithopone has a structural advantage over zinc oxide in oil grounds and underpaintings because its films tend to dry more completely and thoroughly within a comparatively short time, and to be less brittle; but it is inferior and unreliable in whiteness.

Titanium whites are extremely inert and are unaffected by all conditions which pigments are likely to undergo, including temperatures up to about 1500° F. When first introduced they were expected to replace lead and zinc whites both for this reason and because of their greater opacity and covering power; but although they are valuable additions to the list of pigments and find a continued wide use, they have certain properties which limit their application when they are ground in oil. When exposed to severe tests, their films have a tendency to become both soft and chalky; hence they are most successful as pigments for oil painting when zinc oxide, which tends to form hard, brittle films, is added in amounts varying from 20 to 50%, as is done in white house paints and enamels. In coloured or tinted mixed paints, 40 to 50% of zinc is used, and for oil grounds on canvas 50 to 60% of zinc is probably the best proportion. When ground in oil as an artists' colour and compared with zinc and flake whites, the titanium whites may occasionally turn more yellowish upon short ageing. The pigment itself does not change; the yellowing is apparently a surface effect of the oil. The reason for it is possibly that because the pigment is so inert or non-reactive it does not form the same combination with the oil that the more reactive zinc and lead do, and therefore favours a more pronounced or thicker continuous oil layer in the upper part of the film, somewhat like that in the glossy paint diagram on page 129. This yellowing is not extremely bad; it is scarcely apparent when tinting colours are used with the white. The titanium whites are rather poor driers in oil, although more rapid than zinc white; titanium and mixed zinc and titanium oil grounds must be well aged before use.

In aqueous mediums, titanium is entirely satisfactory. In tempera mediums the difference between it and flake white is reversed. In tempera, flake white usually brushes out with difficulty; titanium brushes well. Pure dry titanium dioxide is sold by one maker under the trade name of Kronos; the product described in the list of pigments as titanium pigment (made with barium sulphate) is sold as Kronos Standard T. Other kinds of less value in artistic painting are also produced. The pigment made with barium is the one

in common use; the pure oxide is somewhat more expensive (but still in the low price class) and, in industry, is employed less often—usually only when extreme opacity or hiding power is required. Some painters dislike it in tempera and prefer the barium composite because the pure oxide is so very powerful that it is difficult to wash out of the brush. The English and American titanium products are pure, uniform, and well made. According to Toch[102] the material as ground in refined linseed oil for artists' use shows none of the defects enumerated above, and under the conditions of artistic oil painting is a thoroughly satisfactory and reliable pigment.

The titanium pigments have the greatest opacity and the highest tinctorial power of any of the whites. If a grey is made by mixing one part of black with 10 parts of Kronos, by volume, approximately 25 parts of Kronos Standard T will be required to produce a grey of equal intensity; using white lead, 40 parts will be required, and using zinc oxide, 60 parts. The greys produced by mixing black with white lead appear neutral or warm in comparison with the cool, bluish greys of zinc and titanium.

It will be seen that although neither of the defects of white lead is present in zinc and titanium, and although white lead has none of their defects, we have no entirely perfect white for universal pigment use.

Inert Pigments

The inert fillers or extenders are, as has been mentioned elsewhere, white or nearly white pigments which have low refractive indices and, therefore, when ground in oil in the manner of the usual artists' colour, have little or no opacity or tinctorial effect. They are used as cheapeners or adulterants, and to impart to oil paints various properties, such as bulk, tooth, reinforcements of the film, hardness, softness, etc.

When mixed with aqueous binders or mediums, they are less transparent, and in some cases, as in the chalk-glue gesso mixture, several of them will produce brilliant, white, and adequately opaque coatings. When chalk is mixed with oil, it will form a muddy, translucent paste more intense in colour than the oil itself. Coloured pigments which have been reduced or let down with inert materials are muddier as well as weaker than pure pigments.

The following are the more important commercially available inert pigments. Their properties will be found described in the list of pigments.

Alumina hydrate	Infusorial earth
Asbestine	Magnesium carbonate
Barytes	Marble dust
Blanc fixe	Pumice
Chalk	Silica
China clay	Talc
Gypsum	Whiting

Clacium carbonate, chalk, whiting, marble, and limestone have the same chemical composition, and differ only in crystalline structure, density, or degree of purity.

Permanence of Colours; New Pigments

Permanence in an artists' colour means that the colour will not be altered during the life of the work of art in which it is used, by any condition which it is likely to encounter. Some colours may be altered or destroyed by subjecting them to strong heat or to the action of chemicals, but since works of art are not normally expected to endure such conditions, the term 'absolutely permanent' means that a colour complies with all of the normal requirements for pigments as previously listed.

Accelerated mechanical tests for light-proof qualities may be performed in the laboratory. Machines such as the Fadeometer and the Weatherometer have been designed to give the equivalent of years of exposure to direct sunlight and dampness in a few hours. But although every precaution is taken to reproduce the average atmospheric conditions which the colour might be expected to encounter, it is generally conceded that such tests do not exactly duplicate the effect of direct exposure to the sun's rays. However, since the most general objection is that the accelerated tests are too severe, the results furnish a fairly satisfactory index to permanence from the artists' viewpoint; they are indicative if not conclusive. Exposure to natural conditions over a term of years is still the only absolute test of a colour's permanence.

In the past, new discoveries in artificially made pigments were introduced in various ways. Sometimes a valuable colour was allowed to remain in obscurity or as a laboratory curiosity for many years until circumstances caused or allowed its introduction to the palette. At other times, novelties were immediately introduced and later discarded when artists found them to be impermanent or otherwise unsatisfactory. When the aniline colours appeared during the second half of the nineteenth century, painters and others concerned with the permanence of pigments envied the brilliance and variety of these colours but realized that few of them could be utilized for purposes requiring any degree of permanence. About thirty years ago coal tar pigments of greatly improved light-resistance began to appear on the market, and were adopted by makers of decorative paints, printing inks, and other industrial products. Because they were so much more light-proof than the earlier colours, some of them, such as Harrison red, were introduced to the artists' palette, but none was sufficiently light-proof to have warranted their adoption; the degree of their improvement over the older coal tar colours was responsible for the optimism with which they were received. Sometimes new colours which belong to the same chemical family as a successful older one and which theoretically should share the older colour's desirable characteristics, fail under actual test.

Many printing ink and industrial paint pigments have the word 'permanent' included in their names, and they are permanent in so far as their uses are concerned. A brilliant red which will maintain its general hue on a shop sign under severe outdoor conditions as long as the paint film will last (three or four years) has a right to be called permanent for this use; the same pigment used as an artists' paint may fade, at least enough to destroy pictorial

or decorative effects, after five or six years in daylight—even in diffused, indoor daylight.

Not only as regards pigments, but also in connection with paints and varnishes, the artist should remember that his requirements are different from those of the industrial consumer, and that products which are in all sincerity labelled permanent are not always permanent for his purposes. No one expects the paints which are used in ordinary wall decoration to last fifteen years, still less the paints which have to withstand more severe conditions, such as those used on houses, store signs, and boats; yet a material which displayed defects in a work of art after twenty-five or fifty years would certainly be considered a failure by artists.

An obstacle in the way of the adoption of coal tar colours of really superior permanence to light, is that most of them have the property of bleeding or striking through when used with oil or oily mediums. If a coat of white paint be applied over a coat of red which has this property of bleeding, even if the red is first thoroughly dry and hard, the colour will eventually be observed coming through the white—apparently dissolving into the film of white paint, running through it in a streaky or spotty manner, or occasionally imparting a uniform pink tint to it. Some so-called non-bleeding colours are really semi-bleeding, the defect manifesting itself only after a period of years. Bleeding will never occur when insoluble inorganic colours are used and the undercoat is perfectly dry, no matter how finely the pigment has been ground. Any light-proof pigment, regardless of its bleeding or other faults when mixed with oil, may be used in pastel, where such defects are of no significance.

We now have modern coal tar colours of enormously greater light-resistance than those of some few years ago; theoretically, or rather, in the laboratory, some will test three or four times as resistant to exposure as madder lake. Yet we are proceeding very slowly toward their adoption, and today we await the results of very exhaustive tests before including such colours in our permanent palettes. Among the most promising of these colours at present are lakes made from a dyestuff known as Hansa yellow, which retains its colour three times as long as alizarin in the Fadeometer, and lakes made by the phosphotungstic process whereby the basic dyestuffs (the most brilliant and varied series and ordinarily among the most fugitive of the common aniline colours) may be made into lakes of superior light-resistance. Alizarin or madder lake, which is universally accepted as a necessary and permanent colour for easel paintings, provided they are kept under the normal conditions of preservation of works of art, might well be adopted as a standard of permanence for such pigments. They would then be required to equal it in all respects when subjected to tests.

Many thoroughly permanent inorganic colours which have been known for years have never gone beyond the laboratory stage because of economic reasons. With the development of new industrial processes, such as the colouring of lacquers and plastics, mass production of some of these becomes feasible, and occasionally a pigment of known reliability is thus

made available to artists for the first time. Manganese blue is a recent example.

Limited or Restricted Palettes

Although it is possible to produce a fairly useful range of hues by mixtures of black, white, and the three primary pigment colours, red, yellow, and blue, we find that, owing to the various qualities of the substances we use as pigments, there are many specific colour effects which can be obtained only by employing a multiplicity of pigments. Depending upon the desired colour key or tonal harmony of the painting as a whole, a complete range of colours can sometimes be effected with a very limited palette, but usually a free choice of pigments is required. Whether the desired result be harmony, contrast, monotony, harsh brilliance, or softness, it is not obtained by merely matching the local colours of nature, but by translating, transposing, or manipulating the tones and colours within the chosen key. A spot of colour which in one painting is garish and brilliant might be a dull blight on another picture.

If a painter limits himself to one red and chooses light cadmium, he will be able to approximate the tones of the duller earth reds with mixtures, but he must forgo the tints and glazes that alizarin will produce. The number of greens, both vivid and subdued, that can be made by utilizing all the permanent green, and yellow pigments, is unlimited; no painter could possibly want all of them in a single landscape. Yet an arbitrary limitation to too few pigments—for example, to one cadmium yellow instead of two—will obviously handicap him in most instances. A full complement of colours is not only useful for local colours but is equally valuable in extending the range of effects by playing one tone against another or by utilizing the contrasts between the colour properties of pigment other than those of hue.

The choice of pigments is entirely a matter of the individual's purpose and intentions. It may be guided by the requirements of the school of painting to which he adheres, but it must be controlled by an understanding of the properties and potentialities of the pigments, each of which requires some study and experience.

The most legitimate technical reason for the limitation of a palette is that painting with too great an assortment of ready-made colour effects results in a defect similar to that produced by overmanipulation or by the use of tiny, timid brushwork, referred to elsewhere. Students are taught to work with few colours as a method of discipline, just as they are taught to work with large brushes, but the arbitrary elimination of useful colours is an unnecessary handicap to mature painters.

Some schools of painting have placed a taboo on the use of certain colours; in the recent past there was a prohibition against brown. This was the result of the revulsion of painters against its universal use in the nineteenth century. The lavish use of black to obtain variations of shade and tone throughout a picture gives a certain unmistakable character to the work. Some painters

desire this effect; others abhor it to such an extent that they exclude black pigments from their palettes. The discovery that some effects of an admired old master can be duplicated by utilizing certain pigments in a definite way, has caused entire groups of painters to allow all their work to be dominated by that method, whether or not it is suitable to the particular case.

In the remarks on perspective it is noted that an illusion of recession or the third dimension may be produced by analysing and translating to the picture the effects of the atmosphere and light on the colours of objects in nature. Whether the treatment of a picture is realistic, objective, or abstract, forms are depicted through the media of line and of colour masses. The development of Western art has established a general feeling that they are of equal importance in a painting, and usually the terms, rules, criticisms, and evaluations applied to the line in a picture can also be applied to the colour. If a painting is considered in the abstract, without any regard to its artistic or pictorial meaning, its forms may be seen to be influenced to a considerable extent by the artist's choice of pigments.

Investigators have studied the palettes of noted painters of the past and present; in some cases painters have produced works of sufficient range of colour for their purposes with as few as two or three pigments. Among others, the books of Church,[30] Fischer,[36] and Hiler[37] contain lists of various painters' palettes.

Lead Poisoning

The use of white lead and other compounds which contain lead has been given considerable attention; most published discussions include warnings regarding their toxic effects. These materials may be handled with perfect safety if the hands and finger nails be well cleaned after using them, and if one is careful not to breathe or swallow the dust. Lead is a cumulative poison; that is, if small amounts are absorbed into the system there is no apparent effect; the toxic effect is built up by added quantities. Workers in factories which produce these products, and house painters who use them, do not contract lead poisoning if conditions are such as to permit the usual precautions. White lead is poisonous only if swallowed or inhaled; on the whole its hazard has been somewhat exaggerated.

Testing of Pigments

Paint manufacturers and other industrial consumers subject their pigments to certain routine examinations and tests, the simplest of which are noted here and described rather fully. They may be further simplified under certain circumstances.

It must be understood that positive, accurate data from tests can be secured only by experienced technicians; also that modern industrial requirements often call for more accuracy in tests than can be obtained by these simpler methods.

These tests are comparative; a newly received sample of a colour is compared with a standard colour kept by the consumer for the purpose.

As a matter of routine, a record of all tests should be preserved in a notebook in full detail.

Colour Rub-Outs. A weighed amount of the standard pigment is placed on a slab of plate glass or smooth stone, and sufficient linseed oil is added to produce a stiff paste when rubbed with a steel spatula or palette knife. The oil is added drop by drop, the number of drops being noted. Care is taken to gather the paste neatly into a small area of the slab, and to rub not more than is necessary to secure a smooth, uniform paste. The paste is then rubbed with a glass muller (page 124), using a uniform, slight pressure, and a back-and-forth, somewhat circular motion, the idea being to grind over the entire amount of paste with each complete rub as much as possible, rather than to spread it over the slab. After 25 rubs, the paste is scraped from the muller and slab, gathered into a pile, and given 25 more rubs.

Using the new sample, the procedure is repeated, the same amount of oil being added regardless of the consistency which results. The two rub-outs are spread on a strip of thin, clear glass, their edges just touching each other, and are viewed by daylight.

Pigments for use in water or varnish mediums, etc., may be tested by rubbing them in those mediums instead of in oil.

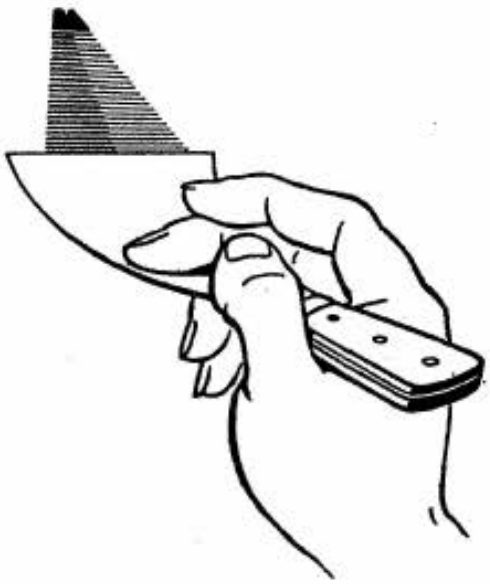
Strength (Tinctorial Power). One tenth of a gram of the pigment is rubbed up with two grams of a standard pure zinc oxide, as described above. For the very powerful colours—e.g., Prussian blue and the blacks—the proportion is made 50 to 1 instead of 20 to 1. For testing whites and pale yellows a standard Prussian blue is used. The figures are given merely as a guide and are varied according to the requirements and preferences of the user. The reductions should be enough to disclose all the tone qualities and to allow slight differences in strength to be easily perceptible, but they should not be carried to the point where weaker colours become so pale that an estimate of their relative strengths is difficult. Strength rub-outs are always thoroughly mulled, and if there is any streaking they are given further mulling until the colour is uniform and thoroughly developed.

Draw-Outs. Another method for comparing the relative colour and strength of artists' oil colours which may be used on prepared tube colours as well as on dry pigments is the one which is used by the printing ink trade, which values pigments for their transparent undertones as well as for their top tones or body colour. The dry colour is weighed out and rubbed up with oil as in the previous account, or samples may be squeezed out of two tubes of prepared oil colours and placed side by side at the end of a wide, flexible wall-scraper (described on page 185).

The handle is grasped in such a manner that when the blade, loaded at the tip with the two dabs of colour, is drawn across a pad of white bond paper, pressure can be controlled. The first part of the stroke is light, and a thick layer is thereby transferred to paper; after one-half to one inch of this has been applied, the knife is held vertically, and with a firm, scraping pressure it is

drawn across the paper with a rather rapid stroke, which will produce a thin staining of the paper. By holding this draw-out against the light, comparison of the two samples is easy, and minute differences in colour, clarity, strength, hiding power, etc., may be almost quantitatively estimated. Try this with an alizarin lake oil colour of known high quality and a students' grade colour made of genuine pigment let down with inert material. An experienced technician can judge the percentage of difference or variation quite accurately.

Volumetric Method. As mentioned on page 116, the evaluation of artists' paints on a basis of weight does not seem to me to be rational. The painter uses his materials by volume rather than by weight, and a direct volumetric method of comparing the relative tinctorial strengths of pigments is better suited to his purposes. A simple apparatus* may be used to determine the relative tinctorial strengths of tube colours by volume. It consists of an optically plane glass slab in which two cavities of unequal sizes conveniently



proportioned (usually 8 to 1) have been accurately hollowed out. The smaller is filled with the colour paste, and the larger with a standard white in oil; both are levelled off with the edge of a metal scraper and the two volumes mixed together.

Other means of measuring small volumes of oil colour in convenient amounts and ratios can be improvised. Ratios of 20 to 1, and in the case of the very low-strength pigments 10 to 1, are customarily used in testing prepared artists' oil colours. Note the method described under No. 22 on pages 451–2.

Dry Colours. Dry pigments are compared by placing small piles side by side, covering them with paper or cellophane, and pressing the paper down firmly and smoothly with a palette knife. When the flattened surface of the

* This is not marketed in Britain but there are many optical instrument makers who would construct it. The template mentioned on page 451 under 22a, being but a metal plate with two circular holes cut in it in a ratio of 20 : 1, is similar in effect and cheaper.

combined piles of colour is viewed by daylight, the line of demarcation and any differences in shade are easily seen. A drop of turpentine placed where the pigments join will bring out the variation in tone with white or inert pigments.

Fading. Pigments and coatings are tested for lightproof qualities by painting them out on a test piece and exposing them to direct sunlight, preserving an identical duplicate in the dark. In the case of coatings which contain drying oils, a fair test would be to allow the duplicate to dry in normal diffused daylight for a month before putting it away. An accelerated test for such coatings is noted on page 156. When oil paints are subjected to long outdoor exposure the samples must be varnished before being compared with each other to compensate for alterations due to decay of the vehicle. Samples on water-colour paper may be exposed in a photographic clamped printing frame with a strip of black paper or cardboard protecting part of the sample for comparison. See paragraph 19, page 450.

Dyes and Lakes. None of the approved inorganic pigments is soluble in water, oil, or the volatile solvents; if any solution occurs upon testing, it indicates that organic or coal tar colours are present. The simplest way to test this is to dust or blow a little of the pigment on filter-paper or white blotting paper moistened with the liquid; any solution of dye colour is immediately apparent. The same filter-paper test is used for soluble dyestuffs to distinguish between single dyes and mixtures of dyes.

Lighting. Colour comparisons should be viewed by daylight; most of the artificial daylight lamps are unsatisfactory substitutes. Although an even north light is preferable in the greater number of cases, direct bright sunlight is sometimes useful in examining blacks and other very dark colours.

Further Refinement of Pigments

The following outline is intended for the use of painters or groups of painters who may have occasion to use pigments free from water-soluble impurities in sufficient quantity to warrant the trouble of washing pigments which are otherwise of high quality. These instructions are not given as recommendations for common use.

The impossibility of the average colour manufacturer's producing pigments especially for artists' use has been mentioned previously. Some of our permanent pigments contain small percentages of impurities which do not detract from their utility in common industrial applications or even in the ordinary artistic techniques, but which are undesirable in some cases where requirements are more exacting—for instance, in fresco painting.

The usual impurities will be small amounts of water-soluble salts, acids, or alkalis, which can be removed by subjecting the pigments to a few additional washings in hot water, using such simple inexpensive apparatus as is employed in the laboratories of the colour makers for their small-scale experimental batches. The manufacture of pigments in general does not require very complex equipment (except in the case of special furnaces for those

pigments which are made at high temperatures), and jars, beakers, little tubs, and filters may be considered as miniature colour factories. The actual manufacture of pigments from their raw materials, however, calls for a high degree of skill and much specialized experience—an inexperienced person cannot expect to manufacture small batches of colour that will equal the commercial pigments either in purity of colour or in pigment properties.

The dry pigments are mixed with water, preferably distilled water, boiled, allowed to settle, the clear water poured off, and the procedure repeated until all of the impurity is dissolved and washed away; then the mixture is filtered and the pigment dried and pulverized. The washing may be done in laboratory beakers of 500 to 1000 ml. capacity, depending on the quantity of colour needed, and an ordinary large glass funnel and folded filter-paper may be used for the filtering. A more satisfactory filter, however, is one assembled from a common laboratory vacuum (aspirator) pump, which is a simple affair made to be attached to a water tap, and connected by a rubber tube to a suction-flask with a rubber stopper into which is fitted a Buchner funnel. The funnel and suction-flask come in various sizes; the funnel is made of porcelain, and has a flat, perforated surface within it, upon which is laid a sheet of coarse filter-paper. After the pigment has been boiled with several changes of water, it is poured onto the filter, and, preferably just before the pump has extracted all the water so that the remaining filter-cake becomes cracked and the noise of suction changes, it is washed again by pouring boiling water upon it. Then, after the pigment has been sucked free of superfluous water, the funnel is disconnected and the pigment turned out on a piece of paper and allowed to dry at ordinary room temperature or with mild steam heat; strong heat may make it cake too hard. The washing vessel should be large enough so that the settled pigment occupies only one-fourth to one-third of its capacity, and the suction flask should be large enough so that it does not have to be emptied too often, which is inconvenient.

All of this equipment is of the commonest kind and is available at any laboratory supply store. If beakers are used they should not be heated over direct flame but should rest on the usual asbestos discs. If enamelled pots are used, they should be of best quality acid-proof white enamel.

It is best to know the nature and extent of the probable impurities so that the wash water can be tested for their presence, by simple qualitative methods; acids and alkalis are detected by the use of litmus, phenolphthalein, or other indicators; and the presence of salts by adding a few drops of the usual test solutions.

Dryness. In large-scale factory procedure, after the washings, the moist pulp colour from the filter press is broken up and spread out on open trays of screening or lath and either air-dried, steam-heated, or put through a mechanical drier, according to the nature of the pigment. It is then pulverized and packed in bags or barrels; so long as it is a fine, smooth powder with no tendency to form hard cakes, it is universally considered bone dry for practical purposes and is within the range of tolerance for any normal painting technique. Some artists preserve their pigments in glass jars with ground

glass stoppers in order to exclude atmospheric moisture (see pages 122, 125) but for all practical purposes the less expensive screw cap jars and friction top cans will serve as well. In reasonably well-conditioned rooms, they may even be stored in paper bags. When absolute dryness is required for very special cases, the pigment must be desiccated by chemists' methods. A harmful or abnormally high moisture content would be apparent by a tendency of the pigment to form itself into firm cakes or lumps.

Colour and Light

The colour of a pigment is not one of its definite, inherent properties; it is rather the effect on the eye produced by that particular substance under certain circumstances. Many conditions can alter the colour effect of a material, and two examples of the same pigment will not match each other exactly unless they are seen under exactly the same conditions.

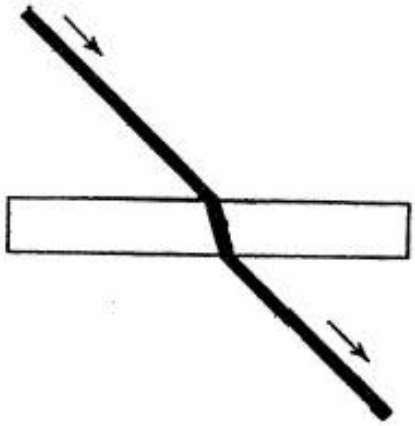
When a dry pigment is mixed with a liquid its colour is changed to a darker or deeper tone. This is an optical effect, which may be explained in the following manner.

The materials used as pigments differ widely in certain properties from the liquids used as mediums. One of these properties is the amount of light a substance reflects and absorbs. All solids and liquids vary from each other in this respect and each one has been measured and tagged with a number which is called its *refractive index.*

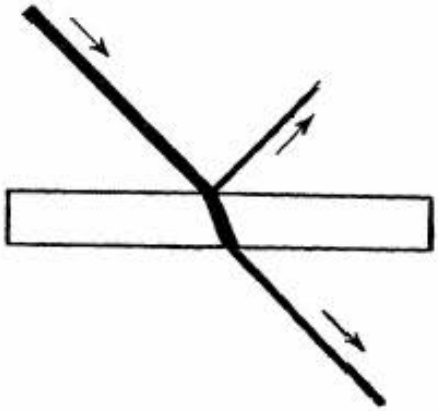
A sheet of glass is a transparent substance; when a ray of light strikes it at an angle, there is a varying amount of surface or mirror-like reflection, depending on conditions; however, the greater part of the light passes through its continuous, uniform structure and emerges refracted or bent, at an angle different from that at which it entered. The refractive index is computed from this change in angle, which depends in each case on the substance's power to impede light rays.

When two substances of varying refractive indexes meet, the greater the difference in their refractive indices, the greater will be the proportion of light reflected at the point where they meet. When a pigment with a refractive index of 2.00 is dry, each particle is surrounded by air, the index of which is 1.00, and a certain amount of white light is reflected. When the pigment is moistened with linseed oil, which has a refractive index of 1.48, much less light is reflected, more is absorbed, and the pigment appears darker or more intense in hue.

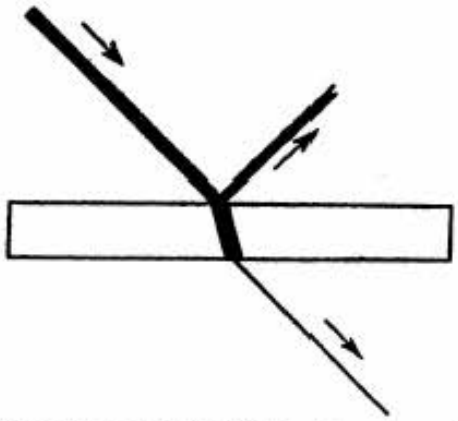
When transparent glass is pulverized, the powder appears white. Water in the form of ice is transparent; in the form of snow it is white and opaque. The reason for this is that while light rays are easily transmitted through the uniform, continuous mediums of the ice and the sheet of glass, when they strike the powdered glass and the snow they are reflected in all directions from the myriads of tiny facets of the particles surrounded by air, and are bent from one tiny particle to another until they become entirely diffused.



Refraction of light. A light ray passing through a sheet of glass or other transparent substance bends (is refracted) and takes a short cut. The angle of refraction varies with each substance and increases according to the power of each material to impede light rays.

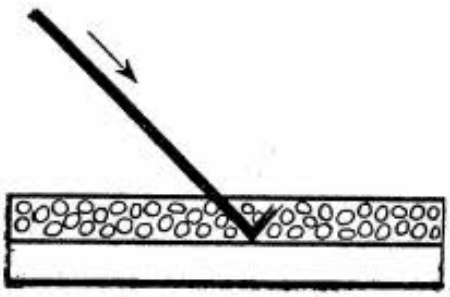


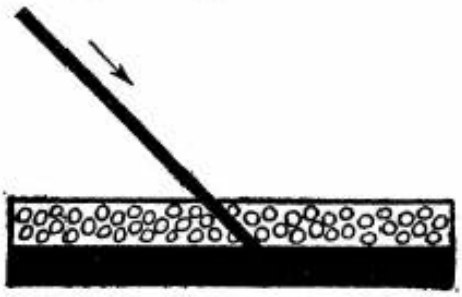
Transmission and reflection of light. Under average conditions a certain amount of light is also reflected from the surface of clear glass as from a mirror. The proportions of light reflected and transmitted vary according to the nature of the substance, the surrounding conditions, and, in many cases, the angle from which the surface is viewed.



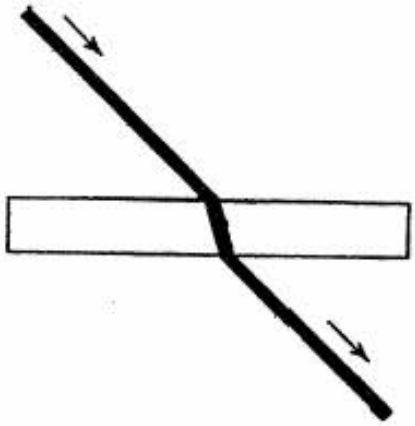
Absorption of light. Thin, translucent milk glass or other semi-opaque material transmits less light than does a transparent material. In this instance, some of the ray is reflected, and some absorbed. The more the light is impeded and absorbed, the greater the opacity.

Dark surfaces. The greatest amount of absorption of light, accompanied by the least reflection, occurs when light impinges on a dead mat, intense black surface. Other considerations being equal, a brilliant white surface will reflect the most light, and as it is tinted the amount of reflection will decrease according to the depth of colour.

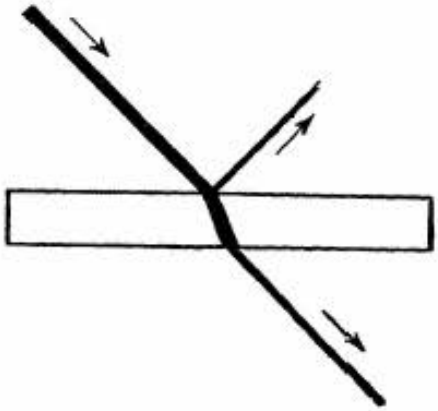




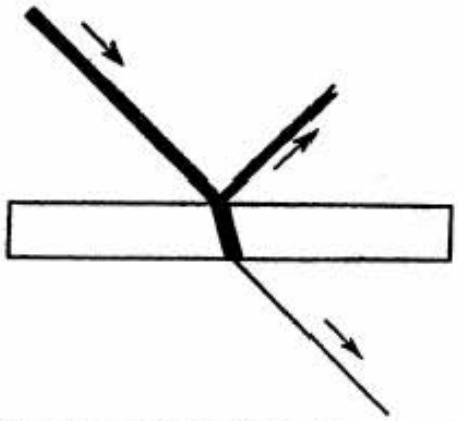
These diagrams show one application of the foregoing principles to painting. When a layer of paint composed of pigment particles and binder is coated on a white ground the resulting reflection of light contributes brilliance and luminosity which are altogether lacking when the painting is done on a black ground. Any colouration of the white ground will tend to lessen the amount of reflection, and the more translucent the coating is or becomes, the more the brightness will be affected.



Refraction of light. A light ray passing through a sheet of glass or other transparent substance bends (is refracted) and takes a short cut. The angle of refraction varies with each substance and increases according to the power of each material to impede light rays.

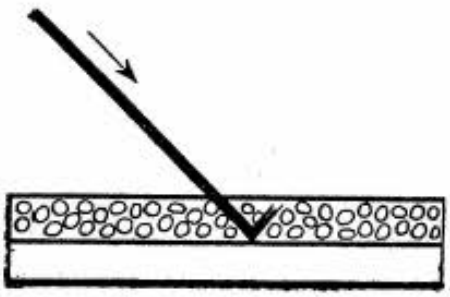


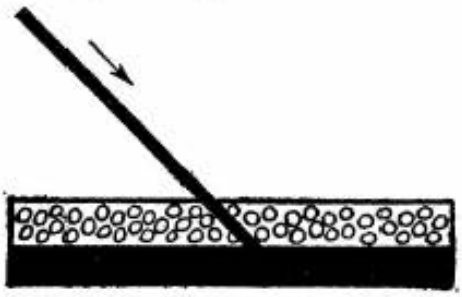
Transmission and reflection of light. Under average conditions a certain amount of light is also reflected from the surface of clear glass as from a mirror. The proportions of light reflected and transmitted vary according to the nature of the substance, the surrounding conditions, and, in many cases, the angle from which the surface is viewed.



Absorption of light. Thin, translucent milk glass or other semi-opaque material transmits less light than does a transparent material. In this instance, some of the ray is reflected, and some absorbed. The more the light is impeded and absorbed, the greater the opacity.

Dark surfaces. The greatest amount of absorption of light, accompanied by the least reflection, occurs when light impinges on a dead mat, intense black surface. Other considerations being equal, a brilliant white surface will reflect the most light, and as it is tinted the amount of reflection will decrease according to the depth of colour.





These diagrams show one application of the foregoing principles to painting. When a layer of paint composed of pigment particles and binder is coated on a white ground the resulting reflection of light contributes brilliance and luminosity which are altogether lacking when the painting is done on a black ground. Any colouration of the white ground will tend to lessen the amount of reflection, and the more translucent the coating is or becomes, the more the brightness will be affected.

When such broken planes and irregular facets exist only on the surface, as when a sheet of glass has been rubbed with an abrasive to produce a ground-glass or non-transparent effect, the light is broken up and reflected on the surface, creating a whitish or frosted appearance. However, since the light-dispersing particles lie only on the surface in a thin layer, the rays are not entirely impeded, and continue on through the glass, which is now translucent instead of transparent.

A flat or mat effect on a paint or varnish film is usually due to the fact that the surface consists of a thin layer of such irregular construction. When such a surface is moistened its opacity is temporarily diminished. In the same way, alumina hydrate, a white, opaque powder when dry, will become colourless and transparent when wetted with benzol because the particles are then surrounded by a medium which has a refractive index very close to their own. The effect of liquids upon the colour and opacity of pigments varies greatly in each case, depending upon the difference between the two refractive indices concerned.

If a pigment which appears transparent or translucent in a thinly applied layer is piled up or applied to a surface in a thick layer, it appears more opaque because the light then travels through a great number of separate particles, each one of which impedes its progress by refracting it, also because there is more reflection of light from the points where the pigment particles and their surrounding medium meet, and because of the increased absorption of light due to the increased number of particles.

Pigments vary in transparency in indirect ratio to their refractive indices, but all of them are transparent to some extent. If the proper medium is selected, laboratory tests can be made which will show that the most opaque colours, even flake white, appear transparent under certain conditions. The liquids used in such laboratory experiments are not suitable for paint medium purposes, but the effect produced clearly demonstrates that hiding power or opacity in a paint film can be lost through a change in the conditions which surround the pigment that has been used. In an actual oil painting this does not occur at once; but in galleries one may frequently find a picture in which, by reason of changes wrought by time, oxidation, etc., the refractive index of the oil film has changed, and a thin coat of paint which originally sufficed to form an opaque film has become sufficiently transparent to allow underpainting or drawing to show through. The effect is called pentimento. Though all opaque pigments have this property, the whites possess it to a greater degree than do the others; pentimento in old pictures usually appears exclusively where white or colours reduced with much white have been used. The fact that all dried films of oil paint tend to become more transparent with age is well established.

It will be seen from the foregoing that when light impinges upon an object it is either transmitted, reflected, or absorbed, depending on the nature of the object; in the case of most paints it performs all three of these actions, in varying degrees.

The practical lesson that oil and tempera painters of the present day have

learned from this is that the ground and underpainting always have some effect on the final painting, even when it is not apparent, and that pictures must be built up carefully with this point in mind.

Correct procedure calls for keeping the ground and underpainting as white or pale as possible, superimposing darks over lights (so far as the nature of the work allows), and, whenever possible, scraping down or removing any substantial thick or dark areas when these are to be overpainted or obliterated for the purpose of making corrections. If two pictures were identical except for the fact that one was painted upon a brilliant white ground and one upon a black ground, the difference between them would be apparent; any departure from the pure white ground or from strictly necessary underpainting will produce an effect which tends toward that of the black ground. It is especially important to use the whitest sort of ground and pale underpaintings when glazes and veils are employed.

Some of the books listed in the bibliography treat light and colour theory in detail from the viewpoint of theoretical optics, of philosophy, or of aesthetics. (Page 464.) Colour and light in their relation to the practice of painting are completely explained by Ostwald[29] and by Laurie.[34]

Colour Effects

Each paint pigment owes its colour to the kind of light rays it absorbs and reflects. White light (daylight) is composed of a number of waves or impulses of various dimensions or wave-lengths, any single one of which, if isolated, would have the property of producing a specific colour sensation on the eye. When a ray of white light falls upon a pigment, the pigment absorbs certain waves and reflects others; this determines its colour effect. Vermilion, for example, will absorb the waves which produce the effect of blue and most of the waves which produce yellow, and it will reflect or throw back the red waves. Ultramarine absorbs almost all but the blue waves; pale cadmium absorbs all but the yellow. Whites absorb little or no light; black pigments absorb most of the light and reflect little. Upon being absorbed, the energy of light waves is converted into heat.

None of the pigments in use, however, produces a pure colour sensation; we can consider them faulty or impure in this respect. Vermilion reflects a certain amount of yellow along with the red; alizarin reflects some blue with the red; therefore we call vermilion a yellowish red, and alizarin a bluish red.

Another reason why body colours do not give a pure colour sensation is that they reflect from their surfaces, as from a mirror, a certain amount of white light, which dilutes the intensity of the colour to a variable degree, depending on the nature of the surrounding medium, as previously explained.

The three colours mentioned so far are called primaries; when any one is mixed with another a secondary colour effect is produced: green, violet, or orange. This system of colour mixing is known as the subtractive process, because the second colour subtracts or absorbs still more waves from the white light than the first colour did. When three or several more pigments

of different colour are mixed, tertiary or broken hues are obtained. Because of the 'impure' nature of the colour effects of our pigments (each one reflecting some waves of a length different from the dominant one) all mixtures will contain blends of minor components, and the effect of any mixture of two colours is invariably duller, less brilliant, or muddier than that of a single pigment. Viridian is a clear, bright emerald green of pure tone compared with any imitation which could be made by mixing a blue with a yellow, because it reflects none of the red waves that such a mixture would reflect. Similarly, painters realize that mixtures of three colours will be still more 'broken'. A complementary colour is one which will absorb the entire portion of white light reflected by another. Red and green, blue and orange, yellow and violet, are the three simple pairs of complementaries.

Light waves have often been compared with sound waves; two different musical notes may be played on two different instruments so as to blend into one clear, simple effect. But if we take two different chords, orchestrate each, and play the orchestrations simultaneously, the result will be complex, if not confused. Laurie[107] suggests an analogy between light waves and radio waves: pigments are substances which have the property of tuning in on certain light waves.

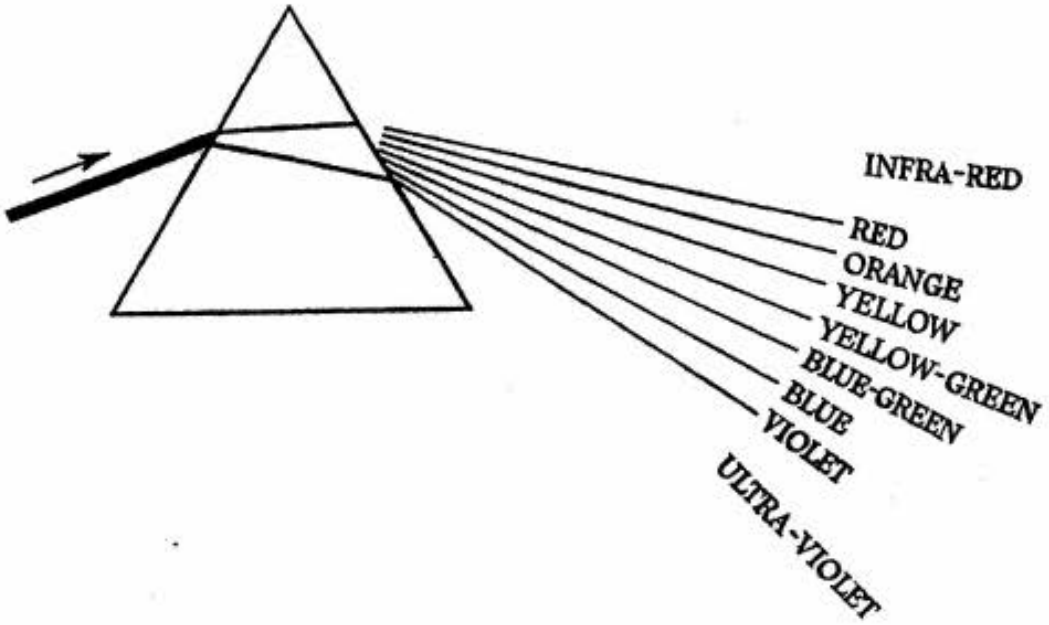
When a transparent pigment is mixed with a white for tinting purposes it does not function entirely as though it were a body colour by imparting to the mixture the colour effect of its surface colour to the mass, but its transparency has much to do with the clarity of tone produced by the mixture. Tints or mixtures of opaque colours are usually duller. When two opaque pigments are mixed, the tiny particles of each, when viewed under the microscope, will appear intermingled, lying next to one another. Rays of light will be reflected from each; the amount of white light reflected from the surface will be the sum of that reflected from all the particles of both pigments. When a transparent pigment, such as alizarin, is used to tint a white paint, the effect is as if each particle of white were surrounded by an envelope of the transparent red; light will pass through the transparent particles, the amount of reflection of light from the surface will be less than when two opaque pigments are used, and what reflection there is will tend to come mostly from one source—the opaque pigment. Fischer[38] points out this property of tinting colours.

Occasionally upon the drying of a paint there will be a colour change which is an exception to some general physical or optical rule. This is always because of some peculiar physical or chemical property of the materials involved. For instance, painters who use aqueous mediums in opaque techniques, such as gouache or casein, will note that greys or other mixtures containing black pigments sometimes dry darker instead of lighter. This may be explained by the fact that, because of the relative density and fineness of the various pigment particles or because of some other physical properties, a movement of the dispersed particles has occurred while the film was still wet, and the black has floated toward the surface. Paint behaviour is not ordinarily erratic; under similar painting conditions, similar results may be expected;

and the painter who has learned the characteristics of each of his pigments is able to control their effects.

Additive Colours. When white light passes through a prism it is broken up into its component parts and the rays emerge in the familiar rainbow or spectrum arrangement, the rays at the red end having the longest wave length and those at the violet end the shortest. The angle at which the rays are bent, or refracted, is greatest at the violet end, and least at the red end. The infra-red and ultra-violet rays are invisible under ordinary conditions.

By recombining coloured rays, we can mix coloured light as we would mix body colour; but in this case a scarlet red, a medium green, and a blue violet are the three primaries, and the system is called additive because the mixed hues are obtained by adding light rays instead of absorbing or sub-



tracting them. The effects of transparent or glaze paints (as opposed to opaque or body colour paints) are a little like that of additive colours, because transparent pigments reflect less white light from their surfaces than do opaque pigments.

The followers of the French Impressionist school utilized the additive process by substituting the juxtaposition of small spots of pure colour for mixtures of colours. When viewed from an adequate distance the light rays reflected from these adjacent colours merge, producing upon the eye a blended hue sometimes entirely different from that which would have been produced had the colours been mixed on the palette. The effect is clear and has a peculiarly vibrant, luminous quality. A similar effect, as all painters know, is produced when mixed colours are not too thoroughly blended on the palette but are rather loosely scrambled on the canvas. This additive behaviour of light rays explains many peculiarities and tendencies in colour mixtures, though it plays a minor role in our painting methods.

Diffraction Colours. A colour effect which often occurs in nature, or which may be produced by manipulations of certain materials, is that caused by the refraction of light in all directions without the use of pigmentation. The brilliant colours of certain plumage and minerals are caused by the diffraction of light from surfaces which have structures equivalent to myriads of tiny lenses or prisms. The iridescent colours in soap bubbles or oil films on water are explained by the fact that very thin films will display iridescence when surrounded by two mediums of different refractive index. In the case of the oil film, the two mediums are air and water. These effects have little to do with painting. They are characterized by an intensity, a brilliance, and often a hue of almost metallic quality, which can be only approximated in paint.

3

Oil Painting

For about three hundred years the oil painting process has remained the standard technique for artistic painting. Although all the other techniques are practised for certain advantages they have over oil painting, the latter remains standard because the majority of painters consider that its advantages outweigh its defects and that in scope and flexibility it surpasses water colour, tempera, fresco, and pastel.

From the viewpoint of permanence, however, all these accepted and time-tested methods of painting may be considered to be of equal merit. They all possess certain inherent defects which the careful painter does his best to minimize, and each presents peculiar difficulties which he must overcome. Materials for each must be carefully selected; oil paint, tempera, and fresco must be correctly manipulated and applied if they are not to deteriorate; and the fragility of water colours and pastels requires that they be carefully preserved.

The basic points of the oil technique's superiority over the other accepted methods of permanent painting are:

Its great flexibility* and ease of manipulation, and the wide range of varied effects that can be produced.

The artist's freedom to combine transparent and opaque effects, glaze and body colour, in full range in the same painting.

The fact that the colours do not change to any great extent on drying; the colour the artist puts down is, with very slight variation, the colour he wants.

The dispatch with which a number of effects can be obtained by a direct, simple technique.

The fact that large pictures may be done on light-weight, easily transportable linen canvases.

The universal acceptance of oil painting by artists and the public, which has resulted in a universal availability of supplies, highly refined, developed, and standardized.

Its principal defects are the eventual darkening or yellowing of the oil, and the possible disintegration of the paint film by cracking, flaking off, etc.

* Some painting methods and materials must be more carefully or precisely applied than others. With some, the range of variation or modification is small, and standard procedure must be closely followed; others are more flexible and a considerable degree of latitude is permitted within the bounds of sound practice. The word flexible used in this rather abstract sense to describe technique in general, as in its more literal meaning as applied to a physical property of materials, does not signify an infinite degree of elasticity; it must always be understood that there are definite limits to such a range.

The former may be eliminated or reduced to an acceptable minimum by correct selection and use of materials, and the latter by correct handling of the technique.

PAINT

Paint consists of finely divided pigment particles evenly dispersed in a liquid medium or vehicle; it has the property of drying to form a continuous, adherent film when applied to a surface for decorative or protective purposes.

As noted in the first chapter, surfaces may be coloured or decorated by applying the pigment directly; in pastel painting the protective function may be supplied by a fixative, the application of which is separate from the decorative or colour application; and in fresco the ground itself supplies the adhesive or binding property. However, paint, in the commonly accepted meaning of the term, usually implies a material which combines these functions—as the typical oil or tempera paint.

When a drying oil is used as a medium for painting, it performs the following four functions:

1. *Executive.* It allows the colours to be applied and spread out.
2. *Adhesive.* It dries and acts as an adhesive, attaching the colours to the ground.
3. *Binding.* It locks the pigment particles into a film, protecting them from atmospheric or accidental mechanical forces and from being disturbed by the application of subsequent coats of paint.
4. *Optical.* It has an optical effect, bringing out the depth and tone of the colour, and giving it a quality different from that which it possessed in the dry state, as discussed in the section on *Colour and Light*.

Drying Oils

A number of vegetable oils have the property of drying to form tough, adhesive films either by themselves or when assisted by the action of added ingredients. These oils do not 'dry up' in the ordinary sense of the evaporation of a volatile ingredient, but they dry by oxidation or absorption of oxygen from the air. The drying process is accompanied by a series of other complex chemical reactions, and the dried oil film is a new substance which differs in physical and chemical properties from the original liquid oil; it is a dry, solid material which cannot be brought back to its original state by any means.

The increase in weight or volume of the oil through the absorption of oxygen is compensated for to a variable degree by the loss caused by the passing off in gaseous form of certain by-products of the reaction. These changes may be measured in the laboratory and from such figures we gain considerable knowledge of the properties of our oils. This subject is given further mention on page 311.

Linseed Oil

Linseed oil is pressed from the seeds of the flax plant which is grown in all temperate or cold climates. The seed from each flax-growing region has its own characteristics and is rated in quality accordingly. The impurity which is principally responsible for variations in quality is foreign or weed seed. This is true of any commercial vegetable oil. Sometimes foreign seeds are added deliberately.

The production of linseed oil is a highly developed modern industry in which considerable scientific work is constantly being done to promote economic efficiency and the uniform production of oils which will have the best properties for the various uses to which they are applied. Because of the relative insignificance of the quantities that are used for artists' materials, scarcely any of the results of this research work are directly applicable to our purposes.

The seed is crushed and the oil is extracted from it by pressing it in special machinery, usually with the aid of steam. The use of steam is necessary to secure the most economical results, but the quality of the oil thus produced is very definitely inferior to that extracted by cold pressing, especially from the artist's viewpoint. The hot pressing extracts a larger percentage of substances from the seed; and despite any subsequent refining to which the oil is subjected, these substances diminish the effectiveness of the oil in just those properties which are most important to the artist. Cold-pressed linseed oil should be the only kind used in artists' materials, but because the steam-pressed oils are adequate for all industrial purposes and because there is no large-scale commercial demand for it, the genuine product is often difficult to obtain, especially from American sources. A fine grade of steam-pressed oil, which most nearly approaches the cold-pressed product in purity, method of manufacture, and properties, is widely substituted for it, and even occasionally misrepresented as being cold-pressed.

Oil has also been extracted from the crushed seed by solution with benzine or other volatile solvents. The solution is filter-pressed cold, and the solvent recovered by distillation and used over again. This process yields the greatest quantity of oil, but it also extracts from the seed a further amount of impurities, some of which add extremely undesirable characteristics to the oil. The residual cake of pressed seeds which is ordinarily a valuable by-product of the regular process and sold as a cattle feed, is so low in nutritive value that it cannot be used; hence this process of extraction has attained little commercial importance.

Freshly pressed linseed oil is a cloudy, impure product; before it can be used in paints or varnishes it must be refined—freed of the moisture, mucilage, albumen, colouring matter, and other impurities which have been pressed from the seed along with the oil.

Raw Linseed Oil. The usual procedure is to warm the crude oil slightly and allow it to stand in tanks for some time (up to two years), during which period a considerable amount of solid mucilaginous sediment or foots settles

out and falls to the bottom of the tank. Oil from some seeds will soon purify itself to a great degree in this manner, but some varieties will throw down foots indefinitely.

After such partial purification the steam-pressed oil is fairly clear but of a rather dark yellowish-brown colour, sometimes with a pronounced greenish tinge, and it is sold as raw linseed oil. It is not used in this form in artistic painting or to any great extent in the better interior commercial paints and varnishes, as it is inferior in nearly every respect to oil that has been further refined, with the possible exception of its durability under extreme weather conditions when employed in an outside house paint.

Cold-pressed oil properly aged and filtered has a medium or pale golden colour, and is used for pigment grinding purposes without further refinement.

Refined Linseed Oils. For most paint purposes steam-pressed linseed oil requires further refining, and the usual commercial treatment is to mix it with sulphuric acid and water, which removes the bulk of the undesirable impurities and improves its colour. This procedure is carried out on a large scale with special equipment, and the best grades are subsequently purified of all traces of water and acid. Many variations of this method are in use, employing a number of bleaching agents and other chemicals. The refined paint-grinding oils range in colour from pale straw to golden or golden amber.

As a general rule, I am inclined to favour the use of paint-grinding linseed oils which have been refined to a golden or light amber colour rather than those which have been bleached to a very pale straw colour, because many of the latter have a tendency to revert to a deeper tone on ageing (see page 110). However, some of the best grades of modern pale oils are processed without chemicals by the use of superheated steam, refrigeration, and other mechanical means, which greatly increase their colour stability.

Varnish Linseed Oil. The refined oils discussed above meet the requirements for materials used in ordinary painting or paint grinding. Another class of refined oils is produced commercially for use in clear varnishes, etc. The first requirement for a varnish oil is that it should be free from 'break'. When linseed oil is heated rapidly to 500° F. and a flocculent mass, or cloud of particles, forms in the oil, it is said to break; oil which remains clear is acceptable as non-break oil. This break contains a large percentage of phosphorus and is not to be confused with the foots which the oil precipitates spontaneously as it ages.

Another specification is that varnish oil should have a low acid number (see pages 312–13), whereas for maximum wettability and dispersion of pigments, paint-grinding oil should have a relatively high acid number. The common method of refining varnish oils is to use alkali instead of acid in the treatment, but some of the best grades are also processed by mechanical methods. It is doubtful whether the simple cold-mixed varnish mediums of the artist absolutely require such oils, and where any great difficulty is encountered in obtaining them, a good paint-grinding oil may be substituted.

Stand Oil. When linseed oil is heated to 525–575° F. and held at that

temperature for a number of hours, an internal change takes place, and the physical and mechanical properties of the resulting product, stand oil, are not the same as those of raw oil. The change is a molecular one, polymerization; nothing is added to the oil and nothing is lost. Stand oil is a heavy, viscous material of about the consistency of honey; it may be thinned to a painting consistency by mixing it with several parts of turpentine, the mixture being paler in colour than other linseed oils. Owing to its viscosity and its low acid value, it is not so suitable as a vehicle with which to grind pigments, but when diluted with a thinner it is one of the most useful ingredients of glazing or painting mediums, as an addition to oil paints or tempera emulsions and as an ingredient in varnishes. Stand oil turns very much less yellow with age than raw oil does, and when it is diluted or mixed with other ingredients to a usable consistency, the resulting medium is practically non-yellowing.

One of the most striking characteristics of stand oil is its levelling property, that is, its tendency to dry to a smooth, enamel-like film, free from brush marks, and its ability to impart this tendency to paints and mediums when it is added to them. For satisfactory results, stand oil can be made only by large-scale industrial methods from selected varnish-type oil. High-quality pale stand oils are now made by heating the oil in special equipment, under high vacuum or in an atmosphere of carbon dioxide. Formerly, stand oil was made in open kettles and heated for as long as 18 hours or more; the resulting products were dark, not uniform, and were partially oxidized. The modern light-coloured polymerized linseed oils have great colour stability and, unlike the oils refined by other processes, are not so liable to revert to darker colours.

The product specifically called stand oil is made to conform to a standard range of viscosity. Some polymerized oils are made in lighter grades and some in very heavy consistencies, so heavy that they can scarcely be poured. Even when thinned with turpentine to the same consistencies as those in which the true stand oils are used, these varieties have working properties considerably different from those of stand oil. Lithograph varnishes are very similar to stand oil, but in general it is not a good practice to substitute them for the latter because they are usually made by variations of the high temperature process which are designed to impart special properties for use in the preparation of printing inks.

Blown Oil, Bodied Oil, and Boiled Oil. Linseed and other drying oils may also be thickened or bodied by an entirely different change, oxidation or combining with oxygen. This is the same process by which the oil dries when exposed to the air, and it results in a product far inferior to stand oil, although resembling it in superficial properties. Oxidized oil is produced by blowing air through the oil; heavy, viscous blown oils are prepared commercially in large quantities. They should not be confused with stand oil. Boiled oil is a misnomer; the oil commonly sold under this name is not boiled but heated with driers until very slightly thickened. A good deal of the boiled oil of commerce is raw oil to which liquid driers have been added; such oil is

derisively called bunghole boiled oil to distinguish it from heat-treated or kettle-treated oil. Neither boiled oil nor blown oil should be used for permanent painting.

Sun-Refined or Sun-Bleached Oil. An older process of refining artists' oils, which apparently dates from the sixteenth century and which usually produces a more rapidly drying product, consists in shaking up the oil with about an equal amount of water, sometimes salt water, and exposing it, in glass jars or trays, to outdoor sunlight for a few weeks. The vessels are loosely covered in such a manner as to exclude soot and dust but admit air, and the oil and water must be thoroughly mixed every day for the first week. It is not possible to name any definite length of time for the exposure of the oil, since the time required varies according to the purpose for which the oil is intended, the consistency and colour desired, the actinic power of the sun in the particular locality and season, the type of oil used, and the size of the container. Gelatinous or albuminous matter is removed by filtering the oil through coarse filter-paper or fine cloths; if a little clean sand is put into the jar at the start, it will help the settling of such impurities. At the end of the treatment the oil is most easily separated from the water by the use of a separatory funnel (see page 438).

The action of the sun and air is threefold; it partly oxidizes, partly polymerizes, and effectively bleaches the oil. Although this oil has been used with good results by past generations of painters, there is considerable opinion that the oxidation part of the process robs it of a good deal of its life, and that it will eventually behave in the same manner as a blown oil or one in which oxidation is begun by the addition of driers; certainly its superficial properties resemble those of a blown oil. If the free access of air is permitted, the oil will thicken to a considerable extent; this action may be retarded by using a narrow-mouthed jug or otherwise limiting the amount of air. Allowing the oil to bleach to the palest possible shade, as mentioned on page 108, is not to be recommended, as there is an optimum degree of permanent bleaching to which any given sample of a vegetable oil may be carried; beyond that point, it will, upon ageing, revert to a deeper colour, a common fault in some commercial bleached oils. The usual correctly refined linseed oil is of a light golden or pale amber hue, not an extremely pale straw colour.

In common with other treatments which increase the viscosity of oil, sun-thickening decreases its wetting power, pigment dispersion, acid number, and free brushing quality, but increases its speed of drying and its levelling and protective qualities. It is therefore more suitable for clear varnish, or glaze and painting medium purposes, than as vehicle in which to grind pigments.

Sun refining is one of the few oil treatments which can be carried on successfully by home methods; as noted in connection with the cooking of varnishes, no heat-treating can be well done by other than large-scale industrial methods, and only the most antiquated recipes call for home boiling of oils.

Poppy and Walnut Oils

Oils pressed from the seeds of the poppy and from mature, rather stale kernels of the common or English walnut have been known and used as drying oils from the earliest recorded times down to the present day. The history of walnut oil is coeval with that of linseed, and that of poppy oil nearly so, but it is interesting to note that these two oils have always occupied a position inferior to that of linseed oil in popularity among painters.

Poppy oil is a naturally pale or straw-coloured oil, and has no trace of the characteristic golden or amber colour of linseed. Whites and pale colours ground in it present a somewhat clearer and more brilliant appearance than when they are ground in linseed oil, and the dried, clear poppy oil film has less tendency than the linseed oil film to turn yellowish. However, because it will turn yellow to some extent under the same test conditions, and because in pale colours even slight changes are apparent, its superiority over linseed oil in this respect is not so great as is popularly supposed. Manufacturers of oil colours are prone to use it for whites in place of linseed oil because it gives their product a more brilliant appearance as it comes from the tube, because the pastes can be stored in bulk or in finished packages more satisfactorily, and because a buttery consistency is more easily produced.

The defects of poppy oil are the frequency with which its paint films will crack upon ageing, and its slow drying rate.

It owes its property of yellowing less than linseed oil to the smaller percentage of linolenic acid it contains, but it is just this difference in composition that causes it to form weaker films. Compared with linseed oil, it dries very much more slowly, its film tends to be softer, spongier, and more likely to crack, particularly when painted in successive coats and especially when the undercoats contain reactive pigments (see page 118) or when the top coat contains very finely divided pigments. In all-round paint qualities I should rate poppy oil as a good artists' material but distinctly inferior to linseed, and one which requires a more careful and precise observance of the laws governing the correct technique of oil painting. This matter is dealt with further in the section on chemistry.

Walnut oil is similarly inferior to linseed oil in all-around paint qualities; some investigators rate it above, and some below, poppy oil. In the past its cost has precluded its wide use for industrial paints; therefore, little modern scientific research has been done on it. It dries more rapidly than poppy oil, being nearly the equal of linseed in this respect.

The finest grades of both walnut and poppy oil are cold-pressed; they may be further refined, bleached, or bodied by the processes used with linseed oil; however, sun- or heat-thickened poppy or walnut oil is not ordinarily in use, because both of these oils are employed primarily as paint-grinding vehicles, where a normal oil consistency is required. Linseed oil is always the choice for clear painting mediums because of its greater durability. Poppy oil has very little odour or taste and is used in France as an edible or salad oil; walnut oil will grow rancid on storage and develop a strong odour, as is common with

other nut oils; its properties as a paint medium are believed to be thereby impaired.

At present the average manufacturer of oil colours uses linseed oil as a basis, and mixes in or substitutes poppy oil, according to his judgment and experience with the various pigments. Although he may be concerned about the ultimate durability of his paints, the immediate advantages of poppy oil are more likely to influence his decisions.

Controversies over the merits of poppy and linseed oil have by no means come to an end, especially as applied to various specific techniques, and some of the foregoing opinions are disputed by other writers.

So far as is known, pure, cold-pressed linseed, poppy, and walnut oils may be mixed with each other in any proportion without any special ill effects.

Other Drying Oils

A number of other oils of vegetable origin have drying or semi-drying properties, and some are used in the paint and varnish industry. For the most part they are inferior to linseed oil and are employed as cheap substitutes for it.

Soya Bean Oil is a widely used industrial substitute for linseed oil, but is distinctly inferior to it. It may be bleached to a very pale colour, but it always requires driers.

Perilla Oil, obtained from crop-grown plants in Manchuria, Japan, and India, is used in industrial varnishes and enamels to impart hardness and toughness. It is not cheap, and is rated as a first class drying oil rather than as a substitute for linseed, but it cannot be used in artists' paints on account of its strong tendency to turn yellow.

Tung Oil (China wood oil) is pressed from the nuts of *Aleurites fordii* and *A. montana*, trees indigenous to China. The Chinese oil is rather dark, has a characteristic odour, and is highly valued as an ingredient of industrial paints and varnishes, where it produces more durable and resistant products than can be made with linseed oil. It has no value as a drying oil unless it is heat-treated and combined with driers and resins; the resulting products are entirely unsuited to artists' use. Tung oil culture has been developing for many years in the south-eastern states of the U.S.A., because of the variable quality and availability of the Chinese product.

Oiticica Oil is a Brazilian product of similar properties. The fatty acids and the drying reactions of both of these oils are quite different from those of linseed and most of the other drying oils.

Lumbang Oil (candlenut oil) is obtained from widely distributed tropical sources, principally from the Philippines. When economic conditions make it profitable, it is sometimes used as a substitute for linseed oil.

Sunflower Seed Oil and Hempseed Oil have properties resembling those of poppy oil, and have been used in Europe as linseed oil substitutes. The drying properties of hempseed oil were known to some of the early writers. They are, however, inferior to those of poppy oil, according to modern investigators.

Safflower Oil is obtained from the seeds of *Carthamus tinctorius* and *C. oxyacantha*, plants which have long been extensively cultivated, principally in India, but also in East Africa, Egypt, Turkey, and elsewhere, for the sake of the safflower dye which is obtained from their blossoms. The oil has been studied as a fairly good possible substitute for linseed, and has been used locally in India in the arts, especially in the decoration of textiles and in the preparation of a sort of linoleum. At present writing, the growing of these seeds and the treatment of the oil are subjects of some industrial research and experiment in America.

Stillingia Oil (tallowseed oil) is obtained from a cultivated tree in China and is widely used for many purposes in that country. It has good drying properties and probably is the traditional material used by Chinese artists to grind the vermilion for the seals which are impressed on their paintings. It is encountered here chiefly as an adulterant in Chinese tung oil.

Minor Drying Oils. About fifty other drying oils are known, but most of them are of minor importance because they are not available in sufficient quantities or because no work has been done on the development of their application to paint purposes. Their sources include the seeds of some common domestic berries as well as seeds from remote parts of the world.

Semi-Drying Oils. A large number of oils which are or could be extracted from seeds, grains, etc., will dry alone with extreme slowness but may be more rapidly dried by the addition of driers, by heat treatment, or by admixture with rapidly drying paints. They are occasionally used to adulterate cheap paints, and sometimes to prevent the settling or caking of heavy pigments in mixed paints. Cottonseed oil and corn (maize) oil are familiar members of this group. Their use always decreases the durability of oil paint.

Non-Drying Oils. Another large group of vegetable oils is altogether non-drying. In some rapidly drying, rather brittle paints or varnishes, it is occasionally possible to add a non-drying substance, the drying action of the coating as a whole being powerful enough to carry the non-drier along with it and produce a finish which is, to all appearances and purposes, perfectly dry. For example, castor oil, a member of this group, may be added to shellac and lacquers to impart flexibility (see page 288).

No animal oils are employed in artistic painting, but for outdoor use, especially on smokestacks, fish oils have been used in industrial paints.

Selection of Oils

Any artists' oil should be a genuine cold-pressed oil obtained from seeds of high quality and purity, and should be properly aged. The following suggestions are made in the order of their desirability.

For Paint Grinding: Oil of a relatively high acid number.

1. Cold-pressed linseed oil, either raw or refined by mechanical means without chemicals.

2. The best grades of industrially refined oil, or sun-bleached oil which has not been exposed to the point where thickening is pronounced or where the colour has become paler than light golden.
3. Poppy oil, especially if all precautions are well observed. To be avoided in underpaintings. A mixture of 50% linseed oil with poppy oil tends to neutralize poppy oil defects, but not to the extent of 50%.

For Glaze Mediums, Clear Varnishes, and Emulsions: Linseed oil of a relatively low acid number.

1. Stand oil or stand oil and turpentine.
2. Sun-refined cold-pressed oil.
3. If an oil of ordinary viscosity is required, a high grade industrial varnish oil, refined preferably by mechanical, rather than by chemical, means.

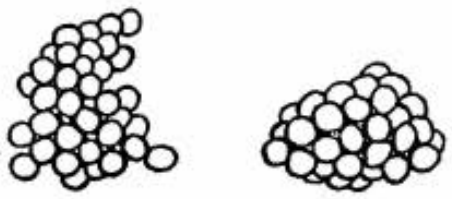
A few painting oil manufacturers are listed on page 441.

Oil Colours

The artists' oil colours which are sold in tubes are made by first mixing oil and dry pigment in a revolving can in which paddles revolve in opposite directions; the product is a stiff, rather dry paste of approximately the consistency and smoothness of peanut butter.

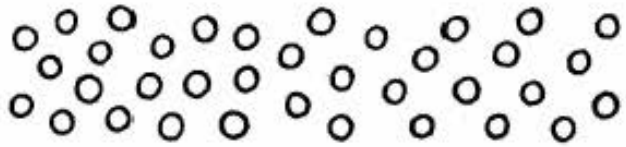
The paste is then run through mills of which the rollers are of either porphyry, granite, or chilled steel; the former alternatives are used to grind those pigments which in the experience of the manufacturer have been found to be deleteriously affected by the steel. The complete and thorough grinding which artists' colours receive exerts some pulverizing action on the pigment particles themselves, but while this is necessary in the case of some of the coarser pigments used in artists' paints, for the most part modern pigments are produced in a sufficiently fine state of subdivision, and the action of the mills in dispersing or wetting the individual pigment particles is at least as important as any comminution accomplished.

After the average pigment has been given its first mixing, the particles* will tend to agglomerate and become surrounded by oil somewhat in the following manner:



* The diagrams in this book which represent pigment particles are not intended to be pictures of single round grains; each individual pigment has a definite structural appearance and particle size when viewed under the microscope; often the particles exist only in the form of clusters. The round shapes in the diagrams represent primary particles; in the case of some pigments these may be individual single grains of various shapes and in other cases the nearest approach to the single grain in which those pigments normally occur.

After a thorough mulling or grinding through a correctly adjusted mill, the agglomerates are broken up, and each particle should be surrounded by the medium, thus:



producing a truly dispersed paint.

The original agglomerates of pigment particles tend to enclose air within their voids; should the dispersed particles in a well-mulled paint settle and come together again to form clumps, their interstices would then contain oil. The instability of a film containing occlusions of air or dry particles is obvious, and the plasticity or consistency of a poorly mulled paint will differ from that of one in which the individual particles are as well dispersed as possible. A great many physical properties of paints are the result of complex physico-chemical reactions which are directly related to the intimate mixture or dispersion of pigments in oil. The diagrams also have a bearing on the explanation of oil absorption, the various pigments requiring various amounts of oil to surround each particle. These intricacies of physical chemistry are, or should be, taken into consideration by modern manufacturers; the only concern which the artist who grinds his own colours by hand has with them, is to see that his paints are most thoroughly and completely mulled.

The operation of mixing pigment and oil on a slab with a sturdy palette knife or spatula represents the manufacturer's power mixing; the subsequent careful mulling is the artist's counterpart of grinding or mulling. Hand grinding or mulling of paints is described on page 123.

The advantages and benefits of grinding one's own oil colours by hand have been mentioned on page 20 and elsewhere; they are almost entirely of a non-technical nature, and involve such considerations as economy, assurance of purity, training in the nature of materials, etc. From a strictly technological viewpoint the product of hand grinding cannot compare with the superior results obtained by the well-controlled use of modern power mills, especially as to the physical requirements of a well-made colour as outlined above. Any qualities produced by hand grinding which are different from those encountered in the usual machine-made product could be duplicated on roller mills, were they desired.

Absorption of Oil by Pigment

In order to grind dry pigments in oil to a usable consistency, an amount of oil beyond that needed to bind and hold the pigment to the painting surface, is required. This amount varies markedly with each pigment, and there is also considerable variation between different grades of the same pigment. The grade of oil used is also a factor in the variation.

The normal amount of oil required by each colour includes what it absorbs plus enough extra, not only to give the proper degree of plasticity, but also to produce the kind of oil film which will correctly lock in and protect the pigment particles. But because oil in excess of the normal required amount is one of the major causes of the yellowing of oil paint and because it is also a factor in some of the structural failures of paint films, the careful painter attempts to keep the oil volume down to an acceptable minimum.

Measurement of Oil Absorption. Paint manufacturers and chemists have worked out oil absorption figures for the various pigments, expressed either in terms of percentages of oil and dry pigment by weight, or in terms of pounds of oil per 100 pounds of pigment. Due to variations in materials from different sources and variations in grinding methods, these figures are not valuable as accurate statements; the methods by which they have been established do not always take into account all the elements which enter into the grinding of colours, particularly in relation to artists' requirements; but they serve as a rough guide to manufacturers in the formulation of their products. The relation between the weight and bulk of the pigments is generally overlooked; the artist is more interested in the percentage by volume than by weight; he does not apply his colour by weight, but in films of a particular thickness, or by volume.

Oil Index

I have adopted the term 'oil index' for a rating of the various pigments as to the relative volumes of linseed oil necessary to grind them to average paste consistencies. The figures serve to indicate whether the paste will contain much or little oil, and how the volume of its oil content compares with that of other pigment pastes. Pigments whose oil indices fall below 75 are low in oil absorption; 75 to 90, medium; 90 to 150, high; over 150, extremely high. Two figures for one pigment indicate that variations encountered in samples of the pigment are so great that there may be said to be more than one grade as regards oil requirements.

Figures of this kind are useful for various purposes; for example, as discussed under *Painting in Oil*, it is not safe to apply a layer of low or medium oil content on top of a continuous film of high or very high oil content, and the following list will serve as a guide.

Low

Aluminium stearate	29	Chromium oxide green	64
Emerald green	47	Cobalt green*	65
Venetian red	54	Cobalt violet (arsenical)*	66
Flake white	56	Zinc white	71
Spanish red*	63	Zinc yellow	72

* Imported pigments. Further details concerning this list will be found on page 313.

Medium		*High*	
Yellow ochre*	76	Prussian blue	96
Cadmium-barium yellow, light	76	Cadmium-barium orange	97
Cadmium-barium yellow, medium (golden)	76	Alizarin red	100
Cadmium-barium red, light	79	Ivory black	101
Cadmium-barium maroon	79	Raw umber*	103
Naples yellow	82	Cerulean blue	112
Indian red	83	Raw sienna*	118
Ultramarine blue	85	Mars yellow	119
Titanium dioxide (low oil type)	87	Mars black	128
		Burnt sienna*	129
		Burnt umber*	136

Very High			
Aureolin	174	Carbon black	164–284
Cobalt blue, domestic	180	Viridian	233
Lampblack	164–194	Cobalt blue	270

In recent years, the previously mentioned importance of physico-chemical reactions as they affect the physical character and behaviour of liquid paints has been realized by makers of industrial paints, and a demand has arisen for pigments treated to meet various specifications, including oil absorption. Specially treated lithopones and other pigments are regularly made with a wide range of physical properties, and if artists' pigments were used in sufficient quantities, no doubt some of them could be turned out to meet uniform requirements as to oil absorption and other properties. For low oil absorption, the pigment is ordinarily treated with a 2% solution of aluminium stearate in benzine, which coats its particles and alters its properties. The amount of aluminium stearate thus introduced into the final paint is negligible. Pigments will absorb varying amounts of stearate, corresponding roughly to their oil absorption figures.

It must be understood that the average pastes which result from grinding colours by hand with a muller will contain considerably more oil than those ground by power mills, and that the texture, wettability, and degree of resistance to dispersion or tendency to form agglomerates may vary enough from the corresponding properties in mill-ground paints to alter some of the relationships indicated by the figures above.

Insufficient Oil in Colours. When the amount of pigment in a normal paste colour is raised above the normal quantity, it is liable to cause the condition known as over-pigmentation, where the colour may become too stiff and firm to be easily manipulated on the palette and brush. In such cases the danger of introducing insufficient binder and the likelihood of the paint's hardening in the tubes on storage should be considered. However, this condi-

* Imported pigments. Further details concerning this list will be found on page 313.

tion can easily be avoided, as its existence should be apparent to both maker and user.

Influence of Pigments on Oil

When a linseed or poppy oil paint dries it undergoes changes which are the result of chemical and physical reactions occurring between the pigments and the oil, as well as changes brought about by the oxidation of the oil. The total effect of these inter-related and complex reactions varies in the case of each pigment. Among the properties of the paint which are influenced by the pigment to a variable degree are consistency, speed and amount of oxidation, and the flexibility, hardness, durability, and colour stability of the resultant paint film.

Examples of some of the most strongly reactive* pigments are white lead, burnt umber, zinc oxide, whiting, and red lead, whose special properties in oil are mentioned under *Pigments*. Some pigments have a beneficial or reinforcing effect upon the paint film; others will tend to impart undesirable characteristics to it. As a general rule, when pigments with opposite properties are mixed they will tend to neutralize each other's defects or to impart their own distinctive properties to a greater or lesser degree. When used in small amounts as tinting colours, their effects are proportionally minimized. Those pigments which are definitely rejected for permanent painting, however, will sometimes impart their defects to mixtures out of all proportion to the amount used.

The oil absorption figures can be used as a guide to the various degrees of flexibility that may ordinarily be expected of layers of paint containing different pigments; in the following lists the pigments are grouped according to other properties they will impart to paints. They are arranged in the order of their degrees of drying activity; the most active member of each group heads its list.

In these lists to an even greater degree than in the oil index grouping, variable conditions of practice and differences among raw materials make it difficult to gauge relative values with scientific accuracy, or to assign even rough index numbers to them. When poppy oil is used, the action of the siccative pigments will be diminished; those toward the end of the list will have little effect; the retarding pigments will produce a more exaggerated effect; films described as hard and brittle will be softer but not necessarily tougher or more flexible, and those described as soft will in that respect be dangerously near, if not beyond, the line of sound, permanent painting.

The oil absorption figures in the preceding section were based on dry colours of the highest type, such as are most likely to be found on the British and American market and used for the best artists' colours. The following

* The word reactive is not here used in a strictly scientific sense; it merely denotes that some action takes place—something happens. For instance, the exaggerated defects produced by Van Dyke brown when it is added to other pigments even in small amounts, are probably more of a mechanical action, as if a very weak and non-permanent resin were added to the paint.

list is based on the average behaviour of prepared artists' tube colours of several of the better makes, European and American. As stated above, the list is a rough indication of the relative activity of the colours rather than an exact rating.

PIGMENT	FILM CHARACTERISTICS
Rapid Driers	
Umbers	tough, flexible
Prussian blue	hard
Flake or Cremnitz white	tough, flexible
Aureolin	hard, erratic
Burnt sienna	hard, fairly strong
'Average' Driers	
Raw sienna	tough, fairly strong
Cobalt blue	rather brittle
Cobalt violet	rather brittle
Red iron oxide (pure)	strong
Black iron oxide	strong
Yellow iron oxide	strong
Cobalt green	flexible, fairly hard
Chromium oxide	flexible, fairly hard
Viridian	flexible, fairly hard
Naples yellow	strong
Zinc, strontium, barium yellows	hard, rather brittle
Some native red oxides	usually brittle
Slow Driers	
Other native red oxides	usually brittle
Green earth	soft, flexible
Cerulean blue	soft, non-elastic
Ultramarine	fairly hard, somewhat brittle
Yellow ochre	fairly strong
Alizarin	soft
Very Slow Driers	
Ivory black	soft
Emerald green	fairly hard
Cadmiums	fairly strong
Vermilion	strong
Alumina hydrate	hard and brittle
Zinc oxide	hard and brittle
Lampblack	soft
Carbon black	soft
Van Dyke brown	soft and weak

Adjustment of Drying Rates in Tube Colours. In order to meet the average painter's requirements for prepared artists' oil paints, the manufacturer usually adjusts the drying rates of various colours so that his entire line will dry within limits that are not so extreme as they would be if the action of each pigment were allowed to proceed normally. In controlled amounts, driers (see page 159) are added to the slow drying colours, and slow drying poppy oil to the rapidly drying colours. The careful manufacturer will resort to a minimum of this sort of adjustment. There has been some controversy on this point; because driers are of no benefit to the ultimate paint film but are likely to lessen its durability, because they may not be compatible with mediums subsequently added by the artist, and because some painters wish to control their own materials entirely, it has been suggested that control by the manufacturer should be omitted. On the other hand, the manufacturers point out that they are in a position to choose and compound the materials more exactly and correctly than the artist can, and that a set of colours of extremely diverse drying actions would not only present executive difficulties but would cause paint films of faulty structure in the work of the average painter, who has neither the knowledge nor the inclination to regulate his colours in this respect.

Stabilizers

Materials other than pure colouring matter and oil are often added to oil colour by manufacturers in order to keep the pigment in suspension and the oil from separating during the period the tubes lie on the dealers' shelves; also in order to impart the desirable short (buttery) consistency to those pigments which normally produce long (stringy) pastes. Because none of these materials contributes any ultimate beneficial quality to the paint film, and because their use or rather their uncontrolled use is apt to have a deleterious effect, there has been some discussion as to whether or not they are to be classed as adulterants.

For a long time painters have been accustomed to expect all colours to come out of their tubes with precisely the same uniform, buttery consistency, and to be capable of being brushed out with more or less identical manipulations. The water-colour painter, however, realizes that certain pigments have poor working qualities in his medium, and he learns to manipulate them with sufficient skill to overcome these faults. Those painters in oil who have prepared their own colours also find that they are able to manipulate the less tractable colours and to make allowances for their various behaviours. Some of the stringiest pastes, such as ultramarine, are colours which are seldom required in the pure, full-toned state but are more often used in small amounts as tinting colours, where this lack of easy brushing quality has little importance. There are, of course, limits to what is acceptable; no painter wants to use very stringy or very liquid colours; but some tolerance can be applied to certain colours, and an exactly uniform consistency should not be required if it means the distortion of other desirable qualities of a pigment.

STABILIZERS

The three classes of materials used as stabilizers for oil colours are (1) waxes or wax-like materials, which produce a colloidal or gelatinous condition in the oil/pigment system; (2) water or aqueous solutions, which produce the same effect by emulsifying the oil; and (3) certain inert pigments, such as alumina hydrate, which produce very short pastes.

The addition of beeswax, or of aluminium and zinc stearates or palmitates, will result in good buttery pastes, and when these are used in very small amounts there is probably little danger of any harmful effect on the structural strength of the resulting oil film. Such materials, however, always have a definite particle structure, which places them in the solid rather than in the liquid class; hence they do not take the place of some of the oil, but replace some of the pigment volume, thereby diluting the tinctorial strength of the paste, just as if an inert loading pigment had been added; for this reason the colour will require a larger percentage of oil.

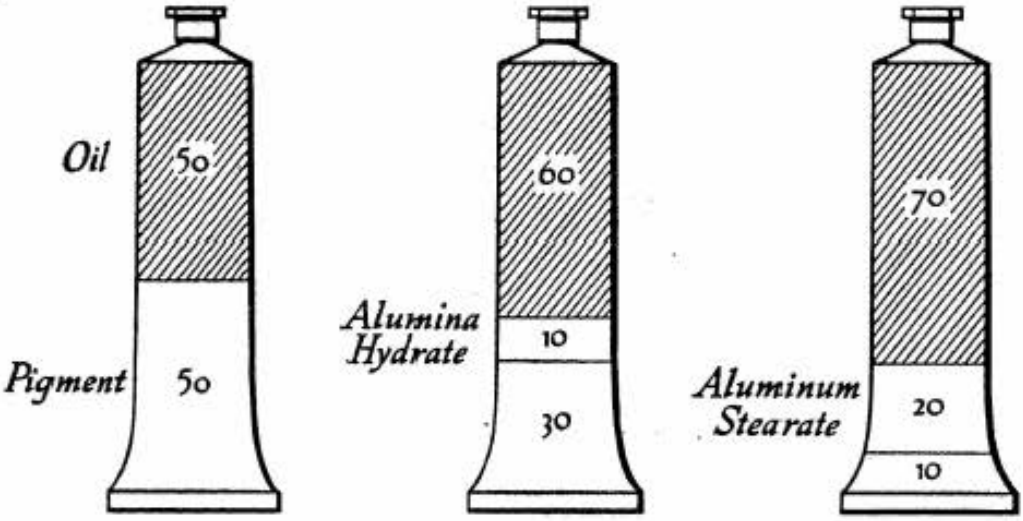
If used in sufficient quantity, the metallic soaps will tend to cause the oil film to become spongy and to get brittle with age. They are also suspected of becoming yellow or promoting the yellowing of oil. To a careless manufacturer, they would present a simple solution of all the problems of colour-grinding, and because they have great bulk and are comparatively inexpensive, they are well suited for use as deliberate adulterants or cheapeners. Judging from the low tinctorial strength of some of the purportedly first-class colours which contain aluminium stearate, their uniform consistency, the comparatively low cost of some of the rarer colours, and the fact that the aluminium stearate is used indiscriminately in all pigments, one would suspect that it is sometimes used in greater amounts than the manufacturers would have us imagine. One to two per cent by volume in the total amount of oil colour is usually considered permissible.

The difference between percentage by weight and percentage by volume, as mentioned in the section on oil absorption, must be considered in this connection, because aluminium stearate is such a light, bulky material. Its specific gravity is 1.01, and one pound ground in an oil paint will bulk about 0.118 gallon, which is over 15 ounces by volume. American chromium oxide, a heavy pigment, has a specific gravity of 5.09, and in paint one pound will bulk 0.0236 gallon, which is only about 3 ounces by volume. This means that if a comparatively small percentage by weight of aluminium stearate, say 5%, is added to chromium oxide, the pigment in the resulting paint will contain about 21% by volume of this non-pigment material. The weight figures are of importance only to the manufacturer and the analyst as a basis for computing the significant or volume figures. The same weight-percentage of aluminium stearate mixed with a pigment of below-average specific gravity, such as ultramarine blue (specific gravity 2.34; one pound bulks 0·0513 gallon, or about 6 volume ounces), would produce a mixture containing more than 11% of aluminium stearate, by volume. This point is brought out in the oil absorption table, where I have included aluminium stearate among the pigments, and it ranks first, or lowest in volume per-

centage; it would be 23rd if the table were arranged in order of percentage by weight.

When waxy materials are used as stabilizers, their action is partially a surrounding or coating of the pigment particles and their agglomerates with a layer which increases the wettability of the pigment and also serves as a sort of lubricant or cushion for the particles within the plastic paste. The use of waxes in colours results in greatly increased oil absorption; for example, cadmium yellow, which occupies 13th place on the oil absorption list, is not greatly altered when 1 or 2% of beeswax is added to it, but when it contains 10% it requires so much oil that it would be placed in the 'very high' group.

When it is desirable to use a stabilizer in home-made colours beeswax is to be preferred. Aluminium stearate and other metallic soaps are produced in many grades and variations; their application involves much expert care; manufacturers prefer them to beeswax for their own purposes and use wax only occasionally, as a plasticizer rather than a stabilizer.



The use of any appreciable amount of water, with or without soap or emulsion-forming materials, is definitely to be condemned, as the resulting films are spongy and will certainly turn more yellow than will the films of water-free paints. According to Toch,[65] ½ to 1% of water may be added to artists' tube colours without detrimental effect. Few of the ordinary dry materials that surround us and are in daily use, are entirely desiccated or free from all traces of moisture—least of all the finely divided pigments, the surfaces of the particles of which expose a large area to the atmosphere. A fairly appreciable amount of 'innocent' moisture may therefore be ground into a paint, depending upon the moisture content of the pigment.

Separation of oil from the pigment is annoying, but unless it occurs to so great an extent that it leaves the pigment in a hard, dry, unusable mass, it is not one of the very worst defects an oil colour can have; it might even be taken as evidence that not too much stabilizer has been used. However, it is more often an indication of improper selection, formulation, or grinding of

materials. When a little excess oil has separated from the paste, it may be removed by spreading the paste out on paper, which will absorb it. If a manufacturer is conscientious in his selection of materials, in his adjustment of proportions, and in his methods of grinding, etc., he will need to use only a minimum of stabilizer.

Students' grade colours are often loaded with considerable amounts of such inert pigments as alumina hydrate, which give them very desirable buttery consistencies but which practically insure their eventual lowering in tone, as the transparent nature of such materials does not mask the yellowing of oil films.

The diagram of the three tubes indicates how the relationship of oil to pigment in a pure colour is altered and the tinctorial strength of the colour weakened by large additions of extenders.

Livering. Oil paint which turns to an insoluble, rubbery mass in the tube or can is said to liver. This is invariably the result of the action of low grade or impure pigments on mediums, or of the action of poorly formulated materials on each other. Pure, high grade pigments correctly ground in the proper oils will not liver.

Hand Grinding of Oil Colours

The grinding of oil colours by hand does not call for particular techniques other than those outlined under *Rub-outs*. The pigment should first be mixed with oil on the slab to a stiff, uniform paste with a sturdy, yet flexible, palette knife or spatula. The straight, rather blunt kind, at least four inches in length, is sometimes more useful for this purpose than the slender, tapered kind generally used by artists. The paste is then ground with a muller, much as described under *Rub-outs*; care must be taken, especially at the beginning of the grind, to gather the paint by scraping it from the sides and bottom of the muller as well as from the slab, and this should be done very frequently during the grinding. In the case of most pigments, a more liquid consistency will develop after some mulling, at which time a little more pigment may be worked in with the spatula if desired. Although the volume of oil is to be kept at a minimum, it will be found, as previously stated, that in order to grind and disperse the pigment particles thoroughly, more oil will be needed than is required to mix the pigment to the stiffest sort of paste.

If it has been decided to add wax to any of the colours, put four fluid ounces of oil in a measuring glass and add white beeswax, which has been broken into conveniently small pieces, until the level of the oil rises to 4½ ounces. Transfer it to a tin can or other suitable vessel and warm it on a stove until the wax melts. Be careful not to overheat or boil. This mixture will contain a little over 11% of wax by volume, and should be diluted with 3 or 4 parts of pure oil for average colour-grinding use. If greater accuracy is desired, the following table shows how many parts by volume of pure oil should be added to each part of this wax-oil mixture to produce paints of various wax percentages. The mixture may become semi-solid on cooling, but at

room temperature will always mix into oil and colour easily. It should be kept in a tightly covered wide-mouthed jar or can.

Volume per cent of wax desired	*Pigments of 50–75 oil index*	75–100	100–125	125–150	*over* 150
1	8	6	4	2	1
1½	6	4½	3	1½	¾
2	4	3	2	1	½
3	3	2	1	½	¼
4	2	1	½	¼	0

As mentioned under its own heading and in the section on chemistry, poppy oil is generally less desirable than linseed oil as a painting medium.

However, pigments which produce poor consistencies in linseed oil will often behave much better when they are ground in poppy oil, which tends to make more buttery pastes and to hold the pigments in suspension more effectively during long storage. In many cases, notably with such pigments as ultramarine, viridian, and certain artificial iron oxides, a small percentage of poppy oil added to the linseed oil will produce shorter and more stable pastes. The minimum amount which will produce this improvement varies with each pigment and must be determined by experience; 25% of poppy oil is as much as can be used without its imparting its undesirable effects; a lesser volume, 10 to 15%, is better if it will give the desired results. Over 25% poppy oil will result in a mixture that will display the bad characteristics of the oil—namely, slow drying, and the formation of weak films liable to crack.

Mullers are hand-made in various sizes, with grinding faces from ¾ inch to 6 inches across. The most convenient size for making test rub-outs has a

2½ inch face and weighs about a pound. For grinding small batches of paint the usual size is 3½ or 4 inches and weighs about 3 pounds. The design of the curve at the bottom edge of the muller is regarded as being important because it should create a wedge-like entrance into the grinding surface. In order to increase the weight of a large muller for some uses, its handle may be encased in a collar of lead; this can be made of strips of sheet lead. Both muller and slab should have a grain or tooth, which may be produced or increased by grinding carborundum, or some other abrasive powder, with turpentine or water on the slab with the muller. Plate glass is the usually preferred grinding slab; white marble or a lithograph stone is occasionally used. The back of a glass slab may be painted white, white paper may be placed under it, or it may be made of opaque white glass.

Grinding should be continued until the paint is acceptably fine and smooth-textured and no grittiness is audible; some of the pigments will be found to offer more difficulties than others; these must receive additional mulling. Because of the larger quantity of paint involved, a larger area of the slab will naturally be covered than in the rub-out tests previously described. The volume of dry colour and the number of drops of oil required in each case may be noted as a guide for future work with the same materials.

Some Notes on Various Pigments. Viridian acts as if it were a kind of powdered glass when first mixed with oil, and it requires more grinding than the average pigment to make a smooth paste; persistent grinding will usually give the desired results; wax is not often necessary. If viridian is used in too coarse a state, it tends to give a blackish appearance. Zinc oxide is one of the colours to which some manufacturers insist upon adding wax to improve the flexibility, to correct the natural tendency to form pastes of a stringy consistency, and to prevent their settling and hardening in the tube. Wax is added to Prussian blue, cobalt green, and aureolin to overcome a granular texture and to such heavy pigments as chromium oxide, vermilion, and titanium white in order to minimize settling or separation of pigment and oil. Ultramarine is perhaps the worst pigment to grind into a buttery paste on account of its stringiness and thixotropic properties; much ultramarine ground in oil and sold in tubes contains so much stabilizer that the difference in strength between it and a home-made colour is obvious. Some of the long or stringy pastes may be somewhat improved merely by grinding manipulations.

Tempera colours are similarly ground in water or tempera mediums, and are more conveniently stored in small screw-cap jars than in tubes. Water colours must be ground very fine; a prolonged grinding with pressure is necessary to obtain the correct texture, as mentioned under *Water Colour*. Fresco colours must be equally well ground. Gouache colours should be well dispersed and smoothly, but not necessarily finely, ground.

Tubes. Collapsible tubes (pure tin only; lead or tin-coated lead tubes must not be used) may be had from some artists' supply stores, and from some wholesale drug houses. The usual 'studio size' is 1 × 4 inches.

The tubes are filled with a palette knife, and enough room should be

left at the bottom so they can be closed conveniently and neatly. If one attempts to cause the paint to settle into the head of the tube without enclosing air bubbles, by tapping the capped end on the slab, the shoulder of the tube is certain to be bent or dented. To avoid this, the tube is grasped lightly in the hand so that the cap is protected from contact with the table, and the fist is pounded on the table. The open end of the filled tube is then squeezed together lightly, the tube laid on the slab, and a palette knife pressed down firmly on its end (covering about $\frac{1}{8}$ of an inch of the tube). The tube is then picked up by its cap with the other hand and folded over the blade; this folding is repeated once or twice. The end may then be crimped more securely with a pair of stretching pliers if desired. Do not fill the tubes too completely or they will leak or burst open.

During the eighteenth and early nineteenth centuries, when prepared oil colours began to be an article of commerce and before tin tubes were invented, the colours were kept tied in small bladders which were punctured with a bone or ivory pin in order to squeeze out the colour. The pins had large heads and were replaced in the puncture to seal it again.

Fine Grinding. Considerable differences of opinion formerly existed as to the proper degree of fineness to which pigment particles should be ground, but most investigators now seem to agree with Ostwald[29] that there is an optimum degree, which varies with each pigment. Doerner[38] warns against overgrinding by commercial makers, and says that the character of the colours is often lost thereby.

I am of the opinion that altogether too much concern is felt for the supposed overgrinding of pigments by the manufacturers of tube colours. In the first place, the experienced manufacturer is well aware of the optimum degree of grinding compatible with the most brilliant appearance of his product, and he is not going to allow his colours to suffer in comparison with those of his competitors because of being overground or burnt. Furthermore, it is expensive to grind colours fine—the material must be run through the mills several times with a comparatively slow-flowing output. Finally, brilliance, the desired short or buttery quality, and stability of the dispersion are best arrived at by grinding accurately to an optimum point, which varies with each colour but which ordinarily will not be fine enough to injure the physical properties of the colour. Those pigments which are liable to cause structural defects in the film by being too finely divided have seldom been reduced to that condition by the mills; more often it is simply one of their natural characteristics. (See page 114.)

The particles of ancient pigments, especially those which were made from native ores, are often many times larger than those of modern pigments of the same composition. When viewed under the microscope, these coarser pigment particles always appear so much more brilliant and colourful, so definitely characteristic of their type, that on that basis one would choose them as more beautiful. However, when each pigment has been ground in an oil medium it is doubtful whether any difference in colour quality can be discerned; the better structural effect upon the film of the uniformly screened,

modern pigment would be a deciding factor in choice. The older colour makers reduced their pigments to as fine a powder as they were able to in practical production, and they would have pulverized them more finely and uniformly had their equipment been equal to the task.

Some investigators believe that in the grinding of oil colours as it is actually practised, irregularities due to coarse particles are a more likely source of failures and weak points in the film than is overgrinding. All are agreed that uniformity of particle size is most desirable.

Extremely coarse particles of material are occasionally called for as additions to finished paints in some techniques; for example, powdered pumice is sometimes added to grounds to increase tooth, and sand or other coarse materials in order to achieve textural effects. Inasmuch as these materials may be considered to remain outside of the regular pigment/oil dispersed system, it is a question whether or not they have any effect upon the structure and permanence of the paint coating, by either weakening or reinforcing it; they are generally used in comparatively sparse amounts.

An oil colour for artists' use should be ground fine enough to show a smooth, glossy, non-granular surface as it comes from the tube; and when it is diluted to a thin glaze film and applied to a white or transparent surface, no pronounced colour particles or granules should be apparent on close examination. The discussion concerning fine grinding applies only beyond this point, and the artist who grinds his own colour should realize that with the means at his control there is little danger of his going too far; he should grind his colours as fine as he can. With care and attention he should be able to turn out an acceptable product but he should also realize that his colours will seldom, if ever, equal those produced by the power mill, in regard either to complete dispersion or low oil content. His paints will usually contain from 15 to 50% more oil than those made in power mills, and a much lower proportion of completely dispersed, or primary, pigment particles.

The time-honoured method of comparing textures, used by the workers who tend paint factory mills, is to rub small bits of the pastes between the thumb nails, whereby slight differences in coarseness or grittiness are perceived. Coarse particles are easily discerned when a thin layer of paint is smeared on a sheet of glass and held to the light.

The simple mixing of dry colour and oil without mulling is not recommended, as the resulting paint will contain a large excess of oil, will tend to have poor plasticity, and will not make films of durable structure. The pigment will be neither evenly dispersed and wetted, nor completely locked in with binder. If a painter who has become accustomed to mixing pigments and oil lightly with a palette knife, will take some of his product and give it a thorough and complete mulling, he will find that he can usually introduce much additional pigment into the mixture without changing its original consistency. This is ample proof of the presence of excess oil in the first product.

Pigments must always be thoroughly and completely dispersed in an oil paint or an oil ground medium. It is very likely that dry particles, coarse and

irregular particles, and lumps or agglomerations cause weak spots in the film, and may be starting points for cracking of the ground or paint film. When silica or pumice is added to an oil ground for the purpose of imparting texture or tooth, it should be lightly mulled into some of the mixture and not merely stirred in. Aqueous *grounds* (gesso) do not usually require grinding, because of their wetting and binding properties and the peculiar structure of their dried coatings; but aqueous *paints* require careful and complete grinding.

Painting in Oil

There are obviously nearly as many techniques and combinations of techniques in oil painting as there are schools of artistic thought, but the rules which govern the correct application of the oil-painting materials are the same in all cases. Within their general restrictions there is ample leeway for adapting them to individual requirements and to the requirements of the various types of work. It must therefore be understood that in these remarks, as in most published accounts of painting processes, examples which have been chosen are broad enough to cover most of the variations, and have been selected as the clearest or simplest means to demonstrate the principles involved.

The simplest example of oil painting is the production of a plain two- or three-coat system such as applied to walls by house painters. When paint is applied to a canvas, a panel, or a wall for pictorial or decorative purposes, it will act in accordance with the same rules that govern the actions of the common wall paint, and the basic principles of correct application are the same in both cases.

One of the first considerations is that no moisture should be present in the ground, and precautions must be taken to prevent moisture from permeating the film from the rear. Another is that the degree of absorbency of the surface should be uniform. House painters therefore give porous wood and plaster a good 'drink' of very thin shellac or glue size—not enough to produce a non-absorbent, slick surface, but sufficient to penetrate and size or seal the pores.

If a perfectly impervious and solid surface, such as a metal, is to be painted, it is roughened mechanically in order to give it a tooth or key, and the priming coat is composed of materials which have strong adhesive properties and give a surface so coarse that even when sanded to a smooth finish it will still have considerable tooth. Wood or plaster surfaces which have previously been painted must, if their surfaces are smooth or glossy, be roughened with coarse sandpaper or steel wool, so that the ground will have sufficient grain both to take the paint from the brush and to make it adhere well.

In a three-coat system, the first coat should be coarsest in texture, the second of a finer grain, and the third, finest. Likewise, a superimposed coat must be as flexible and susceptible to expansion and contraction as the undercoats. It may be somewhat more so, but on no account should it be less flexible

than the undercoat, or cracking, flaking off, and peeling will certainly occur. An exaggerated illustration of this principle would be to grasp a sheet of rubber that had been painted, and stretch it; the paint would immediately crack in a thousand places. This most important rule of gradation of layers, which applies to all methods of artistic painting, is referred to under *Fresco Painting*; it was known to craftsmen of prehistoric times.

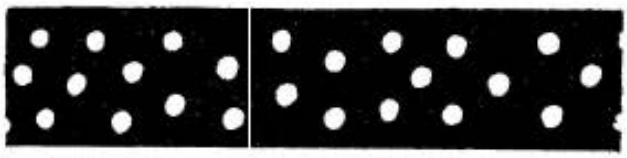
The oil index figures on pages 116, 117 indicate the general order in which oil films containing various pigments may safely be superimposed. There is, of coarse, no definite, precise line to be drawn, particularly among pigments of the same class, and the precautions apply only to pure colours, or to mixtures in which these colours predominate. A good rule to follow is that pigments in the high or very high groups should never be used full strength or nearly full strength as underpaintings for those of lower oil absorption.

The free use of turpentine or its equivalent as a thinner or diluent is a necessary part of the process in all forms of oil and varnish painting, and with experience the painter learns to introduce just the right amount to make his manipulations easy and bring the thickness of his paint layer under control without impairing the structural strength and durability of the film.

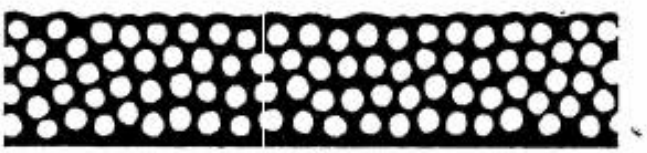
Mat or Flat Finish

The manufacture of glossy and flat liquid paints may normally be regulated by varying the proportions of turpentine and fixed oil or varnish binder, care and precision being required.

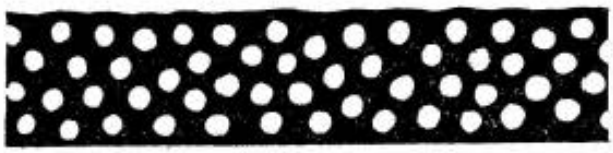
In the formulation of a glossy mixed paint, when the non-volatile binder or fixed oil has greater bulk than the pigment, the dried film produced may be approximately represented by the following diagram, in which the surplus medium has levelled out to a smooth, even surface above the pigment particles.



If a larger amount of turpentine or other volatile solvent be added to the vehicle, so that the fixed oils or resins which form the dried film are of lesser bulk in proportion to the same amount of pigment, still sufficient in quantity to surround the particles and lock them in but not present in large enough proportion to flow out, a rougher surface is produced, and the light, instead of being reflected from a smooth, mirror-like surface, is broken up and reflected in all directions, resulting in a flat (mat) effect, thus:



If an intermediate proportion of binder is present, a semi-flat or egg-shell finish is produced, thus:



The four formulas for wall paints on page 246 illustrate these principles.

In actual industrial practice, these flat and semi-flat effects are sometimes obtained by the use of materials such as aluminium stearate, wax, etc., which cause the vehicle to assume a microscopically wrinkled, porous, or otherwise rough surface; or by the use of inert pigments whose structures are irregular, containing particles in the forms of flat plates, needle-like crystals, etc., which will extend up into the surface film, preventing it from flowing, thus:

If a mat finish is attempted by diluting a ready-made paint excessively with turpentine, the effect may be mat, but the film may also be weakened to such an extent that the pigment is liable to chalk off eventually, or the film to crack or display other defects. The diagram in such a case would show pigment particles surrounded by a layer so thin and porous as to offer them slight protection against being rubbed off or picked up by subsequent coats.

When normally glossy pure oil colours are applied over grounds that are considerably more absorbent than the average prepared artists' canvas, usually enough of the excess oil is absorbed into the ground to produce a mat surface on the painting; but it is not always possible to rely upon such action to produce finished paintings which will present a uniformly mat finish. A fairly exact degree of absorbency must be worked out for the ground if it is not to have the disadvantages of being too absorbent or too impervious as mentioned in the chapter on grounds; it is not always possible to prepare either grounds or paint layers of such uniform quality and thickness that there will not eventually be dull and glossy spots in the picture; the first or direct painting on the absorbent ground will act as a priming coat, upon which subsequent brush strokes will appear more glossy. If the paint or medium contains resins, or is otherwise more glossy than normal oil colour, irregular glossy spots will be still more likely to form. Some painters, however, particularly those whose techniques may be for the most part classified as simple and direct, have succeeded in applying this system of mat oil painting with good results. The use of a final varnish or treatment, after a painting has become dry, to produce a flat finish, is discussed under mat varnishes on pages 154–5.

However, the typical well-painted example of permanent oil painting does not have a mat finish, and paint technologists agree in declaring that durability or non-yellowing properties are sacrificed by attempting to imitate the qualities of tempera, fresco, or distemper which do not naturally belong to the oil medium. Until comparatively recent years, easel paintings in oil were never expected to be other than glossy. The oils and varnishes used in the technique of oil painting are not materials which are particularly noted for their adhesive properties; neither do they give armour plate protection to the pigments; but they do give adequate, durable service under normal conditions. Nevertheless, conditions do not have to be removed very far from the normal to cause abnormal results.

Mat Effect of Aqueous Binders. As a general rule the aqueous mediums, such as are employed in water colour and tempera, contain more powerful adhesives than do oil mediums, and once the correct proportion of pigment and binder is established they may be diluted with their volatile solvent (water) as freely as desired, without the dangers mentioned above (see diagrams on page 19). Water colour in particular may be thinned down to the faintest wash without its permanency's being impaired; the open-textured paper will still hold the pigment particles in its interstices, binding the picture to the surface. With aqueous binders, the mat finish is a function of the pigment; the clear medium, if used alone, would dry to a glossy finish when applied to a non-absorbent surface.

Structure of Paint Films. Scraping fairly fresh layers of paint from a canvas with the palette knife is a good way to reduce overthick layers of underpainting (unless the effect is not in accord with the artist's personal technique), as the surface obtained is technically or structurally well suited to receive overpaintings, and results in the formation of paint films of great durability.

An artistic oil painting with its broken areas of separate brush strokes has a large advantage, as to durability, over ordinary wall paint with its continuous film of uniform thickness. Occasional heavy impasto strokes may safely be used in combination with thinner painting; expansion and contraction due to atmospheric changes or to the flexing of a canvas will not readily cause cracking in such cases. Uniformly thick pasty painting over wide areas, however, soon leads to cracking, because the resulting film acts as a unit in expansion and contraction. The life of house paints, whose formulas sacrifice the extreme permanence of artists' paints for other considerations, is greatly prolonged by correct application. One of the first rules for applying continuous films of industrial paints and varnishes is to keep the layers thin; several thin coats always are preferred to one heavy pasty coat of equal thickness. Coatings applied in this manner are less likely to become defective.

Theoretically, and in the results of laboratory tests, the application of a coat of oil paint over a recently dried layer does not produce such a desirable structural effect as its application over a completely dry film, or over one which has not quite set to dryness. However, this is not a seriously important point in practice, especially when pure linseed oil is used in normal tech-

niques. All other conditions being satisfactory, oil paint may safely be overpainted at any stage, so long as its surface is sufficiently firm to resist being picked up, and so long as it has sufficient tooth or absorbency to hold the new paint.

The spontaneous volume changes and movements involved in the drying of oil films are somewhat different in type from the movements which may occur in dried or aged films. It should be remembered that the former actions are temporary, that is, they take place only once, at the time of drying, during a period when the flexibility of all elements of the paint structure is greater and more uniform than it will be in the finally dried painting.

The movements which affect the permanence of a dried painting and which are induced by external forces—temperature and humidity fluctuations, and the like—are permanent possibilities. A well-painted picture is designed to withstand these forces when they occur in average normal degree; when they occur in extreme severity they may exert their destructive effects at any time during the life of the painting; cracking, peeling, and other such defects are liable to be the result of faulty practice at any time after the various layers of the painting structure have dried and assumed the greater part of their final characteristics.

As a general rule, defects which are a direct result of the application of overpainting while the underpainting is not in the ideal stage to receive it, should occur within six months. The choice of materials and methods for building up a structure that will withstand age and variable external conditions is a more important consideration than the order of painting on newly dried surfaces.

When a dried painting presents a slick or waxy surface upon which fresh paint does not take well, and when it seems necessary to make some provision for the permanent adherence of the new coat, it is better to do so by roughening the surface slightly than by coating it with some foreign material which will add another element to the structure and introduce an additional danger. Roughening the paint surface to supply a key or tooth for further paint may be done by rubbing it gently with a mild abrasive, such as finely powdered pumice, bread, a rubber eraser, or art-gum; in the case of delicate films and glazes, care must be taken not to destroy more paint surface than is intended. Freshly dried surfaces which have become soiled by handling are best cleaned with balls of soft bread. A good retouch varnish can safely be used to bring out dull spots during painting, provided it is kept to a thin layer.

On page 331 there is a diagram representing the dissection of an average oil painting; this may be consulted in connection with the present subject.

Painting Over Old Canvases. The practice of painting over an old picture is certain to lead to unwanted effects; if it is necessary to utilize old canvases for the sake of economy, it is best to remove the entire old painting and ground. If the canvas is soaked in a tub of water overnight, the entire work can sometimes be scraped off the following day, leaving few traces. If this does not work, it is best to discard the canvas. Fresh paint, as previously

mentioned, can be scraped off with a putty knife, and the surface thus exposed usually presents an excellent foundation for repainting. Removal of old paint from easel paintings or walls in a wholesale manner with paint-remover is not be recommended; paint-remover contains paraffin wax which will be left embedded in the surface; aside from this, the action of the solvent is likely to leave remnants of the ground or underpainting, in a weakened condition. Alkaline or acid solutions will also leave injurious substances in the surface.

Old paintings will always show through newer painting eventually, on account of the increasing transparency of the ageing paint film (see page 99). When the brush work of the first picture contains impasto strokes or brush marks even slightly thicker than a thin flatness, ghosts of the original work will show up in a disconcerting manner. The presence in the original painting of reactive materials, especially zinc and poppy oil, and variations in the original film's consistency and thickness all present elements of danger to the final work. Isolation of the old painting with a layer of casein or other material which is dissimilar to the paint, introduces an additional element of complexity and is not in accordance with the rules for the correct gradation of layers.

The following is a résumé of the more important points to be observed in painting a permanent picture in the simple, straight oil technique:

1. Select a support which is stable in itself and sufficiently durable to withstand the conditions under which it is expected to last. Canvas must be securely and permanently fastened to its stretcher and panels must be correctly braced or framed.

2. The ground must possess absorbency, porosity, roughness, or a combination of these properties to a definite degree depending on the requirements of the work and sufficient to create the proper mechanical bond between the surface and the coating. The ground must be as white as possible, and a thin glue size should isolate linseed oil from vegetable fibres.

3. The common procedure (subject to numerous variations) is to sketch or trace a preliminary drawing on the ground with charcoal or pencil. The drawing lines are then usually gone over with very fluid oil paint, containing at least 50% thinner. On gesso-type grounds, thin water colour or ink may be used. Before applying oil paint over charcoal or chalk, the excess particles should be dusted off by flicking lightly with a cloth.

4. If more than one layer of paint is to be applied the first coat should be kept thin and even, as far as the nature of the work permits. Pigments in the high or very high lists on page 117 should never be used full strength in underpaintings; they should be mixed with at least 40% of pigments of lower oil absorption if they are to be overpainted with average colours. Paint must not be applied to completely dried, glassy, non-absorbent underpaintings because of the poor adhesion between such surfaces and fresh paint. Overpainting during the period of from one week to two or three months after oil paint has dried is considered dangerous by some workers, as the paint undergoes shrinkage, but with the possible exception of a complete set

of colours all ground in poppy oil this is not an important precaution. In all further applications of paint, no pigment of low oil absorption should be placed over one of appreciably higher oil content. Thinning with turpentine, especially in upper coats and with thicker films, must be done with care so as not to weaken the resulting film or make it too brittle. Heavy impasto strokes have good durability only when broken or scattered. Continuous thick, pasty layers are extremely liable to crack.

5. Depending upon the thickness of the paint film, a final picture varnish should be applied after the oil paint has dried so completely that all appreciable expansion or contraction in its volume has ceased; it should receive a thin but adequate coat of picture varnish. In the case of a picture of common or average thickness the drying time will be from three to six months. Very heavy paint may take longer, very thin paint less than three months. Extremely thin layers and glazes may be varnished as soon as they have become completely dry to the touch. No oil paintings should be left unvarnished for more than a year, unless they are very carefully stored.

Defects in Oil Paintings

Cracking. 1. Coats of paint less flexible than underlying coats. This condition can exist when the underpainting contains considerable more oil than the overpainting, when it contains a vehicle of entirely different and less brittle composition, or when the top layer of paint was over-diluted with turpentine. The cracking usually appears as an 'alligator' design of fine lines with sharp edges, occasionally quite deep, but more often a surface effect. Cracks from this cause are liable to occur soon after the drying of the paint.

2. Painting over a glossy, smooth, hard surface on which the flexible paint will creep or crawl. Usually the effect is worst when the top coat is thick; it will then display wide fissures with irregular edges, the hard uncracked ground underneath being clearly visible. The technical term for this defect is traction.

3. The use of materials which have the constitutive or inherent property of cracking, either alone or when mixed with certain other ingredients (asphaltum, copal, Van Dyke brown, etc.).

4. Extreme changes of temperature, especially extreme cold. Storage in unheated buildings during severe winters causes a characteristic design of cracks in concentric circles; the cracking usually goes all the way through the ground. Copal and other mixing varnishes are particularly susceptible. The rapid disintegration of old European paintings when brought into steam-heated apartments is well known; panels suffer more than canvases in this respect.

5. Lack of rigidity of support; continual flexing of canvas, or warping of panel. Cracks from such causes are liable to curl up at the edges, and particles will become detached if the paint is brittle. Cracks on panels are long and straight, parallel to the grain of the wood; on canvas, they are fine and crumbly. This is a common form of cracking, particularly in the case of

canvases which have been rolled, improperly stretched or stretched too tight, or expanded (keyed) too frequently after the ground has become brittle. Canvases which have been tightly rolled for a considerable length of time will crack through the ground in long, closely branched veins parallel to the axis of the roll. An ideal rule is that paintings on canvas should never be rolled; when circumstances make it necessary, they should be rolled face out, on cylinders of the largest possible diameter.

6. Faulty grounds. This cause can be detected easily. Gesso over improperly selected wood will crack along the grain of the wood; when cloth is glued to the wood as a backing for the gesso, web-like cracks will appear if it has not been securely glued down.

7. Too much drier. The cracks are similar to those described under No. 1, but are usually wider (see *Driers*).

Poppy oil will crack in the same manner as linseed under all the above conditions; it is generally agreed, however, that its cracking will be more exaggerated and that it will begin to crack under less extreme conditions than will linseed oil. The typical poppy oil crackle under normal painting conditions is likely to result in an elongated alligator pattern with ragged edges along the short sides of the pattern; the fissures are usually wide enough to reveal the ground underneath.

These descriptions of the various types of crackle are not to be taken as infallible; they merely indicate the most usual or likely manifestations. As everyone experienced with the failures of paint films knows, almost any variation of crackle effect may appear as the result of a slight variation in the conditions under which the principal cause operates. Where a crackle effect in oil coatings is deliberately sought after (as in some of the industrial decorative crystallizing finishes) by the addition of certain materials or by the manipulation of oven temperatures, exact conditions must be maintained or the effect will be erratic or unsuccessful.

Flaking (detachment of small pieces of the paint film). 1. Moisture penetrating canvas from rear.

2. See *Cracking*, second paragraph. Inflexible or brittle paint will flake off instead of creeping.

3. Faulty, brittle canvas, especially the cheaper commercial grades. Small flakes of the paint film will become detached, even though the ground itself cracks in larger areas.

4. Variations in humidity. The resulting expansion and contraction of the ground or support will cause brittle paint to flake off.

Wrinkling. 1. Excess of medium; not enough pigment to reinforce film.

2. If in varnish film only, too heavy application.

3. Compression caused by concave warping of panel or by reversed (face inward) rolling of canvas.

4. Use of materials which wrinkle inherently (asphaltum, megilp, too much drier, etc.).

Crumbling or Powdering. Too much thinning or dilution of the paint; too little binding medium; disintegration of binding material.

Blisters are of two kinds. Some are formed by the paint film separating from the ground or undercoat, others by the entire paint film and ground separating from the support. Causes of blisters of the latter type are:

1. Moisture attacking the canvas from the back.

2. Lack of adhesion of the paint film or ground in spots. This may be due to any one of several circumstances: the canvas or ground may have been damp or oily when painted over; the ground may have been too slick or non-absorbent; the difference in composition and physical properties between the two layers may be too great.

Blisters in only the top film of paint and not in the underpainting are difficult to explain. They are usually due to accidental conditions and rarely occur. They may be caused by a lack of tooth in the underpainting or by the presence of small oily or non-absorbent spots.

Darkening or Excessive Yellowing. The use of an excess of linseed oil; the use of copal varnish or inferior oils; the action of sulphur fumes on lead and copper pigments; the normal yellowing of, and absorption of dirt by, varnish on old paintings; the old practice of 'oiling out' or rubbing a picture with linseed or other oil repeatedly, instead of varnishing it. An experienced person can usually determine the cause of a specific case of yellowing.

A normal oil painting requires an average, normal amount of daylight (not direct sun rays) during the time of its drying and for a few weeks thereafter. If the painting dries in a dark or dimly lighted place it is liable to turn dark; should this occur it can be brought back to normal by a week or so of exposure to north daylight. An abnormally humid atmosphere also promotes yellowing during the drying period.

Streamlines. The surface defect resembling drops of water running down a window pane is variously known by painters and paint technicians as frilling, curtains, runs, or tears. When these occur in the varnish film they have usually been caused by applying the varnish while the painting was in a vertical position, the varnish having then set while it was flowing down the surface. If they are in the paint itself, there was too much medium in proportion to the pigment—the paint was too fluid. Picture varnish is intended to be applied while a picture is in a level, horizontal position. When paintings must by reason of certain circumstances be varnished in situ, they may sometimes be treated successfully by methods referred to on page 357.

Varnishes

A varnish is a liquid which, when coated over a solid surface, dries to a transparent film of varying degrees of gloss, toughness, flexibility, and protection, depending upon its composition. Varnishes may be divided into several groups:

1. *Simple Solutions of Resins in Solvents.* Examples: damar varnish, a solution of damar resin in turpentine; shellac varnish, a solution of refined shellac in alcohol. These varnishes dry by complete evaporation of the solvent, which leaves a thin, transparent coating of the pure resin. They can be made

at home successfully. They have been frequently called 'spirit varnishes', but this term applies more accurately to those in which alcohol is the only solvent.

2. *Cooked Oil and Resin Varnishes.* Solutions of resins either natural or synthetic, which are made by cooking them with oils and then thinning with turpentine or its equivalent; driers always added. Example, linseed oil-copal varnish. The drying action is complex; first the turpentine evaporates completely, then the oil solidifies (oxidizes). These varnishes cannot be successfully prepared by other than large-scale industrial methods, attended by expert manipulation. With few exceptions they cannot be mixed with other varnishes and oils without disintegration. The terms long oil and short oil refer to the relative proportions of oil and resin in various types.

3. *Modern Pyroxylin (Cellulose) Lacquers.* These products, made of nitrocellulose, cellulose acetate, viscose, celluloid scrap, and other forms of cellulose, are industrially important, but they are of small value in permanent artistic painting, as their durability is extremely questionable. Their compositions are so varied that it is unwise to use them without first applying tests, especially in regard to darkening on exposure to light. They are generally applied by spraying. The finished products are sold under many trade names, such as Abracol, Cellon, Robbialac, etc.

The cellulose materials used do not dissolve in drying oils, turpentine, or alcohol, and the lacquers are made by dissolving them in special solvents, such as acetone, ethyl acetate, butyl alcohol, amyl acetate, etc.

Tinting colours for lacquers are sometimes ground in castor oil, which generally mixes well with lacquers and also acts as a plasticizer. It is often employed for that purpose alone or together with a miscellaneous list of other substances, most of which have a bad effect on the life of the lacquer. Lacquers, particularly those containing such additions, have delicately balanced formulas, and require expert, experienced care in their manufacture and application. Because of their rapid rate of evaporation, the pigmented lacquers must be ground in ball mills (page 254).

These modern lacquers have good qualities which have been factors in their supplanting the older finishes for coating industrial products; but their principal advantage in this use is their high drying speed, which makes them particularly adaptable to the mass production system. This is notably true in the automobile industry, where they have entirely replaced the older types of coach varnishes. No successful application of these materials to thoroughly permanent artistic painting has so far been accomplished. They have undesirable qualities when used as picture varnishes or as isolating mediums.

4. *Oriental Natural Lacquers.* These exude from trees in a liquid state. They include the original Ning-Po lacquer of China, the industrially important Japanese lacquer, and the lacquers of India, Ceylon, and Burma. None of these varnishes is exported, but each is used for the manufacture of lacquer-ware locally.

5. *Water Varnishes.* These comprise a small group of little importance;

they are either solutions of water-soluble gums, or emulsions of resins. They have no use in artistic painting.

Home-Made Varnishes

The simple-solution varnishes are of the most interest to the artist and, with few exceptions, are the only ones he should use.

The rate of solution of any solid increases when the surface exposed to the liquid is increased; this is ordinarily accomplished by crushing or grinding the solid into fine particles. In the case of adhesive substances such as resins and gums, however, this attempt is defeated by the re-joining of the particles or small lumps with each other, the partially dissolved or softened material forming a solid lump. There are three ways of overcoming this: (1) enclosing the resin in a suspended mesh bag or box which will allow the heavy solution to sink to the bottom of the container, keeping the crushed pieces exposed to the action of the solvent; (2) mixing clean, coarse sand with the powdered material and thus interfering with the adhesion of the particles; (3) continuously agitating the batch with a power device. The first is the simplest and most efficient for occasional home use; the last is the method used in industrial production.

To make simple-solution varnishes, place the resin on cheesecloth, tie or sew the cloth together in the form of a bag, and suspend it in a container of the solvent overnight. Strain the solution through a cloth and allow it to settle for at least a week. The wide-mouthed glass jar, crock, or tin can used should be of such shape and capacity as to allow the bag to be completely submerged in the liquid without touching the bottom or sides of the vessel. The careful worker will regulate the shape of the cheesecloth bag to this end. To prevent too much evaporation of the solvent and also to keep out dust, the vessel may be covered. Sometimes it is possible to rig up a tightly covered jar, the bag suspended by a cord fixed to the cover.

The bag may also be tied to a flat stick which rests on the edges of the vessel, and solution may sometimes be expedited by lifting it occasionally, allowing the heavier solution to drain out of the bag. If one is sufficiently experienced to judge the consistency of varnish without depending on exact formula measurements, or if the purpose for which the varnish is to be employed does not demand accurate measurements, a rapid method is to use an excess of resin, by which means a sufficiently heavy solution can be made in a few hours, the balance of the resin to be dissolved in fresh solvent at one's leisure. Under ordinary conditions from twenty-four to thirty-six hours are required to make a varnish of the usual concentrations; but this varies according to such factors as temperature, type of resin used, and the size of the batch.

On a larger scale, in factories, the resin is vigorously and continuously shaken up with the solvent in a revolving barrel or other agitating device until completely dissolved, and then it is clarified by being run through a centrifugal machine—a much more rapid procedure. If a solution is attempted

by placing the resin in the solvent directly without the cheesecloth, unless it is constantly and vigorously agitated it will form a compact mass and dissolve very slowly. Small-scale shaking or agitating devices operated by small electric motors can be improvised when circumstances warrant their use. Acceleration of the solvent action by the application of heat almost always darkens or otherwise alters the resulting product. A fire risk is also involved.

Simple solutions of resin in solvents, made without oils and driers, are known in the varnish industry as 'cold-cut' varnishes, even though steam heat is occasionally used to accelerate the solution. The various concentrations are known as 5 lb. cut, 8 lb. cut, etc., the figure referring to the number of pounds of resin added to each gallon of solvent.

Uses of Varnishes

Varnishes are used by painters for the following purposes, each one of which demands a product that conforms to certain requirements, as listed under the respective headings:

1. As a painting medium or ingredient in painting mediums for various techniques of painting in oil.
2. As a picture varnish or final coating for oil or tempera paintings, both for protective purposes and to produce a desired uniform finish.
3. As an ingredient in glaze mediums.
4. As an ingredient in tempera emulsions.
5. As a thin, isolating film between coats of paint in certain techniques, and as a size to prepare absorbent surfaces for painting.

The following ideal specifications for a picture varnish as drawn up by the committee on the restoration of paintings and the use of varnish of the International Conference for the Study of Scientific Methods for Examination and Preservation of Works of Art, Rome, October 1930, are quoted in a recent paper*:

'1. It should protect the painting from atmospheric impurities.

'2. Its cohesion and elasticity should be such as to allow for all ordinary changes in atmospheric conditions and temperature.

'3. The elasticity of the paint film and tissues under the varnish should be preserved.

'4. It should be transparent and colourless.

'5. It should be capable of being applied thinly.

'6. It should not bloom.

'7. It should be easily removable.

'8. It should not be glossy.'

The author reports that the 'committee could not recommend any varnish that meets these requirements'.

Our two most generally approved picture varnishes, a pure solution of damar in turpentine and a pure solution of mastic in turpentine or alcohol,

* Gettens, Rutherford J., 'Chemical Problems in the Fine Arts.' *Journal of Chemical Education*, Nov. 1934.

most nearly approach these specifications; mastic turns yellow quite badly with age and also fails to meet specifications Nos. 6 and 8; damar, when carefully made and especially when fortified with a small amount of stand oil (5% or less), will comply with specification No. 6. The most successful non-glossy or mat varnish, as described in this chapter, leaves much to be desired but, as I have noted, gloss is a natural characteristic of the oil and varnish process, and no dead mat finish can equal the durability of a gloss finish. This is true of any kind of painting which employs a binder that locks in the particles or which produces a clear coating in a level continuous film. The compositions of various prepared glaze and painting mediums is discussed under *Glazing*.

Early manuscripts, beginning with those of the eighth century, give a great number of recipes for the preparation of varnishes; until the end of the fifteenth century most of them were rather crude and not applicable to very delicate manipulations. Laurie[20] divides such recipes into two groups: those before 1500, and those of the sixteenth century and later, when alcohol and turpentine were commercially available and the simple-solution and thinned-down oil varnish types came into wide general use.

Most of the older recipes for varnishes up to recent decades of the present century are not to be followed blindly as practical materials by painters who do not have the knowledge and experience to pass judgment on their suitability, and to make adjustments accordingly.

Resins

The natural resins are hardened exudations from trees. Those which exude or are extracted from living trees are sometimes called 'recent resins' to distinguish them from the 'fossil resins' which are dug from the earth or recovered from the beds of streams where they have been deposited by vegetation of former times. Some of these fossil resins are identical with or analogous to resins obtained from living trees in the same locality; others are the remains of completely extinct vegetation.

Resins are insoluble in water, but will dissolve wholly or partially in such liquids as oils, alcohol, turpentine, etc. In the varnish industry, resins are commonly known as gums—damar gum, kauri gum, gum copal, etc.—but when they are considered for artistic or scientific discussion the precise term resin is always used, and the term gum is applied only to water-soluble substances. As the varnish industry is little concerned with the true gums, it uses this term without much confusion. (See page 279.)

Resins vary greatly in properties such as odour, shape, hardness, solubility, colour, and colour stability, and specimens of the various kinds and varieties are easily distinguished from one another. Many resins bear the names of localities; these sometimes represent their places of origin, but more often the ports from which they are shipped. The various species come on the market in more or less well-standardized grades or qualities, each with its own system of grading and designation. The terms bold and sorts both indi-

cate that the grade is largely or entirely composed of clean pieces of the largest size. Grades of resins which consist of small fragments or powder always contain large amounts of impurities and usually considerable low-grade resin. Adulteration with cheaper resins is possible only in these grades; adulterants would be detected immediately among the large pieces of the better grades.

Films of pure resins, as formed by simple-solution varnishes, have a considerably higher resistance to permeation by water vapour than oil films have, but they are less durable in other respects.

DAMAR

Damar is gathered from forest trees, numerous varieties of *Shorea* and *Hopea*. It comes from Straits Settlements, Borneo, Java, and Sumatra. There are many grades on the market; large, clean, colourless, or pale straw-coloured lumps should be selected if possible. The two principal varieties usually available are Singapore and Batavia, named for their concentration and shipping points. No. 1 Singapore is preferred by many for picture varnishes, although Grade A Batavia is more expensive and is considered better by industrial consumers. Sometimes various inferior and less standardized varieties, such as Pedang and East India, are available. These are rather fine points, as the average retail buyer may often have little or no choice. No. 1 Singapore damar comes on the market in whole and broken pebbles and short stalactitic pieces, bright, clear, and transparent, ranging in colour from water-white to a deep straw. The whole pieces appear somewhat opaque, due to a powdery dust of the resin, but the fractured facets are clear. The largest lumps are about 1½ inches in diameter, but the average piece is considerably smaller. Grade A Batavia comes in considerably larger pieces, mostly rounded lumps. Damar resin has a faint characteristic odour.

Although Grade A Batavia is more expensive, No. 1 Singapore is more suitable for artists' simple-solution varnishes; its film is harder and it seems to have less tendency to bloom. One may select his own special grade by picking out the cleanest and most colourless pieces, choosing, say, the best two pounds out of a five-pound lot. When such selected grades were on the market their prices were very high, not only on account of the labour involved but also because more than half of the original material would no longer be No. 1 grade, and had to be sold at low prices for less exacting purposes.

Turpentine is the solvent for damar varnish. While alcohol will attack and destroy a dry film of the varnish, it is not suitable to use as a solvent for damar varnish as the resin is very imperfectly soluble in it. Ordinary mineral spirit will not dissolve the resin cold, nor will it mix with the varnish without impairing its properties, except in the case of very dilute solutions. Many of the more powerful, special solvents will dissolve damar, but are not ordinarily employed for this purpose.

Damar varnish retains its colourless appearance longer than any other

common varnish, because the resin itself contains little or no colouring matter, its slightly yellowish tone being caused mainly by leaves, bark, and other impurities. Fresh damar yields a more colourless solution, the impurities apparently becoming more soluble with age.

Proportions. The customary average formula for damar varnish is a 5 pound cut, or 5 pounds to each gallon of turpentine; this is the varnish referred to as standard damar in this book. For use as a picture varnish it must be thinned with pure turpentine to a usable brushing or spraying consistency, according to the requirements and nature of the work and the judgment of the individual; about 4 parts of this varnish to 1 part of turpentine will meet the majority of brushing requirements. Some of the ready-made grades are a scant 4 pound cut. In the case of such mixtures as tempera and glaze mediums it is added full strength as called for in the formulas. In some instances it is convenient to have it slightly heavier—6½ pounds to the gallon—and in this proportion it is the varnish referred to as damar of heavier-than-average consistency. When a heavy, viscous solution is desired, an 8 pound cut is made. There is ordinarily some waste of resin in preparing varnishes, especially in home methods; this may be compensated for by the addition of a corresponding amount of resin, according to the judgment and experience of the worker—roughly, a little less than an ounce for each pound.

To make approximately one pint of these various concentrations, dissolve the following amounts of damar in ten fluid ounces of turpentine:

5 pound cut— 6¼ ounces
6½ pound cut— 8¼ ounces
8 pound cut—10 ounces

Allowing for the average waste and the loss from impurities, one pound of No. 1 Singapore damar resin when dissolved will bulk approximately 14½ fluid ounces; or one ounce will bulk 0·9 fluid ounce.

While modern practice quite properly lays stress upon accurate control of formulas, an experienced person can judge the viscosity of varnishes by examining the way they flow from a brush or stirring rod. (See also page 156.) Until comparatively recent years, varnishes were seldom made by a strict adherence to standard formulas, but were altered during manufacture according to the judgment of the expert worker, which accounts for the rather vague proportions given in some of the earlier recipes. Because of variations in supplies and circumstances, some painters prefer to depend on experience and the 'feel' of the varnish in thinning it for use, rather than to adhere strictly to exact recipes; they make a heavy cut by placing an excess of resin in the solvent, a procedure more rapid than waiting for all of a given amount to dissolve.

When of the highest quality, damar varnish is straw-coloured and almost clear, the slight cloudiness being due to waxes which are imperfectly soluble in turpentine, but which are clear and transparent when dry. To clarify the damar varnish made according to the method previously mentioned, add a little acetone, anhydrous alcohol, or methanol in very small portions until

the varnish is clear (shaking or stirring vigorously after each addition). When the clarifier is first added, a white, curdy precipitate of wax forms; but it redissolves at once upon shaking.

Partial clarification of the varnish improves its appearance in the bottle and seems to help in preventing bloom; however, the addition of too much clarifier might have a destructive solvent action on underpaintings.

De-waxing. If the addition of these solvents is continued beyond the point where the solution becomes clear, the wax will separate permanently and must be removed by filtration or settling. Removal of wax from damar is not recommended for average varnish purposes, as the durability of the varnish is likely to be impaired. De-waxing is a practice borrowed from the lacquer industry which uses damar resin in certain types of coatings where the presence of these waxes is undesirable.

Impurities in the form of a reddish powder will often settle out of freshly prepared damar varnish. These may be removed by allowing the varnish to settle for a week or so, then straining it through cotton sheeting or other cloth. These impurities are bark or wood dust, and in some cases their amount may be decreased by washing the resin in water, being very careful to dry it thoroughly before putting it into the turpentine. Commercially prepared damar is sometimes cheapened by substituting the offensively odorous steam-distilled turpentine, or by using up to 50% mineral spirit. The former will not affect the quality of the varnish, but the latter may make it dark and turbid. Clear damar varnish sold in cans for industrial finishes is almost always 'improved' by the addition of oils and other varnishes; only those brands made expressly for artists' use and sold by reliable firms should be purchased for artistic work.

Damar varnish, when properly made and applied, has less tendency to bloom than the other picture varnishes. There is no truly non-blooming surface; even a sheet of glass will bloom. If bloom forms on correctly applied damar it will generally be only a surface effect, easily wiped away. (See page 357.) The worst sort of persistent bloom, that which apparently lies below the surface of the varnish, is undoubtedly caused by moisture in the ingredients or by the condensation of moisture on the surface during its drying. The molecular action involved in the evaporation of a film increases its temperature, and minute amounts of moisture are thereby condensed on the surface. This theory has been advanced to explain why some materials have a greater tendency to bloom than others.

The recorded history of damar is not long, but there are many early nineteenth-century references to its use as a well-known, accepted resin, and it is likely that prior to the extensive development of the trade in lands of its origin, the material circulated in Europe under the name of some resin of similar appearance. Early references call for 'Damas, or common white resin', 'Gum de Mar,' etc. According to Barry,[81] the Malayan word damar is not a specific term for the resin, but means torch; flares or torches for local use are made from the trees.

Mastic

Mastic resin is obtained from *Pistachia lentiscus*, a tree which grows in all countries bordering on the Mediterranean. The resin comes on the market in the form of rounded drops or tears, about 1 inch or less in diameter. It has a clear, rather bright yellowish colour which turns deeper and duller on ageing. It is somewhat brittle but softens at a low temperature; some of the finest and largest pieces are used locally as a chewing gum; hence its name. The finest grade is called Chios mastic; it has been known and used since the earliest recorded times.

Fresh mastic dissolves into a perfectly clear varnish with alcohol, turpentine, and most of the more powerful solvents, but it is not soluble in mineral spirit. As a picture varnish, made with turpentine, mastic brushes and flows out to a clear, glassy coating and can be manipulated more easily than damar, but its greater tendency to bloom, and its property of yellowing or turning to a dark brownish-yellow or greenish-brown with age, have made it second choice for this purpose during the present century. The yellowing however, is not so bad as that of copal or other cooked oil-resin varnishes.

When linseed oil and mastic varnish are mixed,* a jelly-like mass is formed which is called megilp (Macgilp, McGuilp, etc.). This material was introduced to the artist's palette in the eighteenth century and it was employed extensively during the nineteenth. Although it was soon realized by intelligent craftsmen that the use of a mastic and linseed oil mixture was disastrous to the life of paintings, it continued in popularity for years, and the failure of many nineteenth-century pictures can be traced to its use as a painting medium. When mixed with oil colours, megilp imparts a marvellous unctuous, buttery working consistency to them, but the picture, after drying, is extremely liable to exhibit all sorts of erratic defects, such as cracking, blistering, turning brown, etc. An old film which contains megilp is so sensitive and soluble that it can be cleaned with solvents only by the most delicate and expert manipulations. For this reason, mastic should not be added to oily glaze mediums, tempera, etc. Its only safe use is in simple-solution picture varnishes which contain no linseed, poppy, or other drying oils.

A pure, straight mastic varnish is made in the same manner as damar; the usual proportions are 6 or 7 pounds to a gallon of turpentine. This solution is heavy enough for practically any use, and requires thinning with turpentine for average varnishing purposes. In alcohol the proportion is usually 2½ pounds to the gallon.

Mastic versus Damar. A summing up of the comparative merits of damar and mastic shows damar to be superior in hardness and wearing qualities, in non-yellowing and non-blooming. Mastic is more easily brushed and levelled to a smooth, even film, and it is perhaps more easily removed or

* The mastic varnish must be of a very heavy consistency and the oil must be boiled or drying oil, or else the gelatinous effect will not be produced.

cleaned from an old picture; but damar's disadvantages in these two respects may be overcome by skilful manipulations.

Some writers state that damar has more tendency to bloom than has mastic; this may be true of inferior grades of damar, but my experience has been the opposite. Repeated tests over a period of many years with a Singapore damar picture varnish containing a little anhydrous alcohol and toluol and up to 5% stand oil, have shown it to be a superior varnish for general purposes. This small amount of stand oil does not interfere with any of the regular requirements of a picture varnish, and it improves its brushing and levelling properties. A recommended formula is 2 ounces of a 1 : 1 mixture of stand oil and toluol to 20 ounces of damar varnish.* A further improvement of these properties may be had by the use of some of the solvents which have slow rates of evaporation, as listed under *Volatile Solvents*. Damar can be mixed with linseed oil to make permanent mediums; mastic reacts with oil and is not used in such mixtures.

SANDARAC

Sandarac is a resin which exudes from the *Calitris quadrivalis* or Alerce tree grown in North Africa. It was widely employed for making protective and decorative coatings as well as artists' mediums from very early times, but has for many years been replaced by other resins. It is quite hard and extremely brittle, qualities which it retains and imparts to the varnishes made from it. It comes on the market in the form of yellowish, opaque tears and broken cylindrical pieces. It is soluble in alcohol and the stronger solvents, and partially soluble in turpentine, mineral spirit, and benzol. It may also be dissolved in oil to make cooked varnishes. Many recipes call for it in varying amounts, usually to impart hardness to mixtures of other resins or oils. In some of the earlier references to sandarac, it is erroneously called gum juniper, pine gum, or white pine resin. Sandarac and mastic, so far as we know, were the principal hard resins widely used by artists in the early days of oil painting. Some investigators suspect that sandarac is the amber mentioned in some of the medieval recipes. For many years it has had little or no industrial significance as compared with the natural and synthetic products which have replaced it. Although simple-solution varnishes made from sandarac will not yellow very badly compared with copal and the other cooked varnishes, they are generally held to be inferior to mastic in this respect.

Damar or mastic can be substituted for sandarac in most old recipes, and if the result lacks the brittle hardness of the original, so much the better in most cases. Sandarac varnishes of the past needed considerable addition of plasticizing ingredients to insure their durability; when damar is used in mediums in combination with stand oil, it seldom requires much oil to produce a desirable, flexible film, and such doubtful plasticizers as non-drying oils, camphor, and the like are unnecessary. Examples of widely used sandarac varnishes of the past are to be found in nineteenth-century recipe books.

* Toch, Maximilian, *Technical Studies*,[111] Vol. II, 1934, p. 149

SHELLAC

Shellac is obtained from the branches and twigs of several species of trees in India, where it is deposited by insects which feed on the sap of the trees. The crude material or stick-lac is refined into a number of grades for various purposes. The best two available on the market are orange shellac, which comes in the form of thin, translucent orange-brown flakes, and bleached or white shellac, which looks like pulled molasses candy. The less refined grades (seed-lac, garnet-lac, and button-lac) are a deep blood-red; formerly this lac was used to make a red dye, and before the aniline dyes superseded it this use was the principal object of its cultivation, shellac for varnishes being a minor by-product.

Both white and orange shellacs are entirely insoluble in turpentine and mineral spirit, but yield cloudy solutions in alcohol. The cloudiness is due to waxes which are imperfectly soluble in the alcohol but which become clear after the varnish film has dried. Many of the more powerful solvents will also dissolve shellac but are not commonly so used.

As a varnish, shellac dries rapidly to a hard, tough, flexible film, and is useful for varnishing floors and furniture. The surface under normal brush application shows a characteristic slightly rough or orange-peel effect. Shellac is not used extensively in permanent painting on account of its tendency to turn dark with age; some investigators also report severe cracking after five or ten years when it is used as a final picture varnish. However, when it has been diluted with pure alcohol to an extremely thin solution, its yellowing is not of much significance, and it may be used as a sizing for porous surfaces and as an isolating layer between films of paint in certain techniques (especially in tempera painting); it has even been sold as a cheap fixative for charcoal and other drawings.

This solution, however, is not to be employed as a retouch varnish or in any clear coating over a painting, for in such uses its yellowing would soon be apparent. Shellac in any work of art must always be well covered by pigmented layers. Its complete insolubility in mineral spirit and turpentine makes it valuable as a size in ordinary wall or decorative painting. Although dry shellac is mixed or melted with other resins and miscellaneous materials to make sealing wax, phonograph records, and other industrial products, the varnish is generally not improved by admixture with other resins and oils. Good grades of the varnish are sold in cans and bottles by reliable makers who state the contents and weight of cut on the label. A specially refined, dewaxed shellac cut with pure alcohol, and quite clear, was formerly called French varnish; but this name now has little meaning. Many inferior shellac substitutes are commonly sold; some of these contain materials added to imitate the cloudiness of true shellac; they are to be avoided, even for household use.

Fresh bleached shellac is soluble in water solutions of mild alkalis; borax is the usual material used for this purpose. These solutions are used as sizes and stiffeners in industry, and for paper, cloth, straw, etc. If shellac varnish

purchased in a can is only partially used, the remainder is best stored in a glass bottle, as it is liable to darken if kept for any length of time in a metal can which has been opened. The white or bleached dry shellac becomes insoluble after a few months' storage, and must therefore be used soon after it is refined.

Other Soluble Resins

There are a few other resins which are or have been used in the preparation of simple-solution varnishes, but they have been more or less completely superseded by other materials both for artistic and industrial use.

Elemi. The best elemi is obtained from a tree which grows in the island of Luzon; it is shipped from Manila and is generally called Manila elemi to distinguish it from inferior varieties which come from Brazil, Mexico, and Yucatan. The purest grade is white, granular, and soft when fresh, but it darkens and becomes harder when aged. Many nineteenth-century recipes call for it to impart toughness and flexibility to coatings for various uses, but it is doubtful whether it is durable or stable enough for use in artists' materials. It dissolves in alcohol, benzol, and the more powerful solvents, and will dissolve with some difficulty in hot turpentine, but this solution is not stable. It has a very low melting or softening point; harder resins, such as sandarac, were usually mixed with it for best results.

Manila Copal. Manila copal or spirit-soluble copal is a term for a number of variations of a resin obtained from trees in the Philippines and the most easterly islands of the Malay archipelago. They vary in hardness and degree of solubility in alcohol. They are not to be confused with the other resins called copals or true copals, and are generally rather inferior for any purpose, being used principally for the cheapest grades of shellac substitutes and for industrial dipping enamels. Manila copal has also been used in fixatives for charcoal drawings.

Benzoin, a resin produced in Siam and also in Sumatra and other neighbouring islands, is occasionally called for in some of the old varnish recipes where it evidently was employed for its odour, as it has small value as a varnish ingredient.

Coloured Resins

Coloured resins were formerly employed not only to impart colour to varnishes, but actually as paint pigments. Coloured varnishes are now made with oil- or alcohol-soluble coal tar dyes, and those resins formerly used as transparent paint colours have long been replaced by more permanent colours, as noted in the lists of pigments. Chief among them are:

Lac. See shellac.

Gamboge. A resin obtained from trees in Siam. It comes on the market in cylindrical pieces made by melting the resin and moulding it in bamboo. It is soluble in alcohol. Its clear, bright, transparent yellow was for a long

time the only satisfactory yellow for glazing, but aureolin now replaces it. Gamboge fades rapidly in bright sunlight but is semi-permanent in diffused light.

Dragon's Blood. A resin obtained from the fruit of an Asiatic tree and shipped principally from Singapore and Batavia in the form of long, thin, cylindrical sticks. Other varieties are occasionally sent from other parts of the world. It is soluble in alcohol, benzol, mineral spirit, and some of the other solvents, but only partially soluble in turpentine. Dragon's blood has been employed for colouring spirit-varnishes a ruby red. Its use as a paint pigment dates from Roman times. It furnished a fairly light-proof colour, but one not to be compared to modern alizarin or even to some of the more light-resisting aniline colours in this respect.

Gum Accroïdes (Xanthorrhoea; black-boy gum; Botany Bay gum). An Australian resin occurring in two principal groups; one has a ruby-red and the other a golden-yellow colour. The resin is used today to a small extent in industrial coloured varnishes, as the colour is satisfactory and quite permanent for certain industrial uses. It has some value as a varnish resin; its film is rather like that of shellac.

Turmeric (curcuma). Prepared from the roots of several varieties of an Asiatic plant. This resin was formerly used to some extent as a yellow dyestuff, and *Aloes*, a resinous material from the juice of a great many varieties of a plant obtained from a number of tropical regions, was used as deep brown. Both of these products were fairly permanent as varnish-colourings, but less so than the better modern synthetic dyes.

Oil-Soluble Dyes. The modern transparent colourings for industrial varnishes, oils, etc., are the oil-soluble dyestuffs. One group of these products are aniline colours of comparatively good permanence but rather dull and limited in colour range; these are chiefly the unsulphonated azo dyestuffs, which are insoluble in water but soluble in oils, resins, waxes, and most of the volatile solvents. A more brilliant and varied but considerably less light-proof series can be made by dissolving some of the regular water-soluble dyestuffs and precipitating them together with a resinate or rosin soap.

Metallic Soaps. The commercial metallic resinates or insoluble resin soaps are of two kinds: fused and precipitated. The first is made by sifting metallic salts into molten rosin and maintaining a constant temperature until the salt is entirely taken up by the rosin. The second method, which produces a more concentrated product, is to cook rosin with alkalies, and after the rosin soap has been formed, to add solutions of metallic salts, when the insoluble resinate will be precipitated. The driers used in paints and varnishes are carefully and expertly made by these same processes; a linoleate is made with linseed oil instead of rosin, a tungate with tung oil, and a stearate with stearic acid.

Some of the metals will produce highly coloured materials. Cobalt compounds of this nature are a deep rose colour; those of nickel and copper are bright green. Zinc and aluminium do not impart colour to their resinates, stearates, etc. According to Laurie,[24] a transparent green of resinous composition was widely used as a pigment in illuminated manuscripts from the

eighth to the fifteenth centuries; this would correspond to a modern fused copper resinate. The earliest recipe he has traced for this material (De Mayerne MS., seventeenth century) calls for verdigris dissolved in Venice turpentine.

Cooked Oil and Resin Varnishes

As previously mentioned, this class of varnishes is not adapted to home manufacture. Aside from the fact that any operation which requires the application of heat to inflammable materials entails a serious fire hazard (fires are of frequent occurrence even in the best-regulated varnish factories and laboratories where provision is made for their immediate control) it has been my experience that the quality of a batch smaller than five or ten gallons is always inferior to that of the usual 50–250 gallon batch, even when made in a modern varnish laboratory by expert technicians. The following resins are the principal materials employed for artists' varnishes of the past.

Resins Used with Oil

Amber. Amber is a fossil resin occurring in beds in the ground; the principal supply comes from East Prussia along the shores of the Baltic Sea, but minor deposits are found elsewhere. It is the hardest natural resin. It has been known from the earliest times, and the Persians and Greeks were aware of its property of attracting straws when rubbed. Amber varnish has a traditional reputation as the varnish *par excellence,* but it is doubtful whether any such product was ever in very wide use. Amber is an extremely insoluble and intractable substance, and as all varnish makers know, most of the old recipes calling for it are unworkable, being either versions garbled through much copying, or deliberate frauds. At high temperatures a little amber can be worked into a cooked oil varnish, such as copal or kauri; the product is very dark, usually black. If any amber varnish offered for sale actually contains amber, it will be in only a very small proportion to the oil and other resins. It has often been suggested that some other resin, especially sandarac, was confused with amber by some of the medieval writers, and so called by them in their recipe books. The term amber was probably more descriptive than specific and may have referred to any currently available hard, transparent resin.

The various early words for amber and varnish have been the subject of much etymological research and conjecture. Beginning with the medieval Greek name Bernice or Beronice, the β of which was altered to a V sound, many names have been used: vernice, verenice, vernition, and vernix. The German for amber is Bernstein or Bernice's stone. The term *vernice* or *vernice liquida* is employed in early writings, and refers to a thick, heavy varnish composed of cooked oil and resins, which was rubbed into panel paintings warm, the picture then being exposed to the direct rays of the sun until dried. The old recipes represent numerous variants of a cooked linseed

oil-sandarac-venice turpentine mixture; few of them are applicable to painting methods in use since the sixteenth century.

Copal Varnishes. To the artist, copal varnish is the most familiar example of the oil-resin type of varnish. The artist who has any concern for the permanence of his work will never, under any circumstances, use copal varnish in paintings or grounds.

The term copal varnish as applied to one specific material means practically nothing. In the current market reports of the varnish industry, a dozen distinct species of varnish resins from many parts of the world, having widely varied properties, are all legitimately listed as copals. Furthermore, from three to ten or more grades of each are regularly on the market.

A varnish which contains a small percentage of any one of these copal resins, plus large percentages of rosin and oil, is always called copal varnish. Kauri, an expensive fossil resin from New Zealand, was at one time called copal and was highly esteemed, as were other copals now absent or rare on the market.

The better kinds of copal are expensive, require the most expert manipulation, and probably never find their way into artists' varnishes. Few manufacturers of artists' materials maintain their own varnish works, and many compounders of paints are ignorant of the composition of the varnishes they buy.

Copal varnishes are made by melting the resin at high temperatures, adding linseed or tung oil and lead or manganese driers, cooking until the drier is thoroughly incorporated, and thinning with turpentine substitute.

These varnishes will always turn dark and are extremely liable to crack with age particularly if mixed with colours, driers, oils, or other varnishes. The easily obtainable grades of fossil copals and of kauri and other natural resins, which are imported from various parts of the world, may be found listed in the weekly market reports of the periodicals that serve the varnish industry. Complete descriptions of them will be found in the books listed in the bibliography. They range from very hard, clear, amber-like lumps to soft, opaque, or dirty materials. With the constant development and improvement of the synthetic resins, these natural resins have suffered a steady decline in industrial importance.

Rosin. Rosin is the resin obtained from gum. Thus, the exudation from crop-grown pines of the southern United States and from similar pines in various parts of the world. It is the residue left in the stills after the turpentine has been extracted from the crude exudation. (See pages 152 and 264.)

Rosin is a clear, transparent, brittle material; it is rather sticky to the touch and it melts at about the boiling point of water. It dissolves in practically all the volatile solvents and oils used in paint and varnish practice. Paints and varnishes which contain rosin are weak, not durable, they will always turn dark and crack, and are so generally inferior that although rosin is used in large quantities for cheaper products, it is considered an adulterant in some industrial paint and varnish finishes. It has no place whatever in paints and varnishes for artists' purposes. Large quantities of it go into

mixtures and compounds for uses other than paint and varnish coatings. Rosin is sold in fifteen grades on the basis of colour and dirt content, as established by the Naval Stores Act*; X, W.W. (water white), and W.G. (window glass) are the palest, being light straw-coloured, and are followed by a series of amber and darker shades designated by various letters of the alphabet in reverse order. Colophony is an obsolete name for rosin; it is taken from the Greek and means 'sound glue', an allusion to the use of rosin on violin bows. Rosin contains a very high percentage of a substance called abietic acid.

Rosin can be hardened, bleached, neutralized, and otherwise refined for industrial use by chemical and mechanical means; the principal grade of this type is called ester gum. Although improved for certain industrial uses, it still retains most of the defects which make rosin unsuitable for use in permanent painting materials.

Asphalts. The properties of some asphalts are noted on page 388. Asphalts have been used on a large scale from prehistoric times to the present for their durability and their water-, acid-, and alkali-resisting qualities in various protective and other technical applications. They cannot be used in any artistic or decorative paints because of the complex surface defects which develop soon after the film sets. These defects are especially marked when asphalts are mixed with linseed oil or other paint mediums.

Synthetic Resins. The synthetic resins widely employed today to produce many of the varnishes for industrial use are complex organic products of considerably varied composition. Each one of these numerous varieties has its valuable qualities, which it imparts to the mixtures in which it is used. Expert technical knowledge is required for the formulation and manufacture of these varnishes. No synthetic resin has so far been placed on the market that can be unqualifiedly adopted for use in artists' varnishes for permanent painting. The main defects of these resins have been their comparatively rapid yellowing, their eventual disintegration by cracking, crumbling, or becoming brittle, and their incompatibility with traditional materials.

As in the case of pigments for semi-permanent industrial uses, many synthetic resins bear designations such as non-yellowing, long-lived, etc., but, as with these pigments, such designations are often relative; permanence in an industrial varnish or lacquer does not mean the same thing as permanence in artistic painting. At the present writing no variety has been found that is better than the approved natural resins for use in making simple-solution or cold-cut varnishes which meet all the requirements for artists' materials. The most successfully formulated industrial varnishes made from these products require many additional materials, such as oils and plasticizers, and the poor ageing qualities of some of these added substances often contributes to the failure of the varnish.

When an improved, permanent synthetic resin can be adapted to artists' use, it will be welcomed, because the best of our natural resins leave much to

* There is no Government grading of Rosin in Britain. The U.S.A. standards are accepted here.

be desired. The most promising synthetic varieties at present are the alkyd, acrylic, and vinyl types. So far, very little work has been published on the use of the synthetic resins in artistic painting or sculpture, and at present this remains one of the interesting subjects for investigation.* Secrecy surrounds the composition of the few prepared artists' materials made from synthetic resins now on the market. This condition will remain until these materials become more standardized. Synthetic picture and retouch varnishes which are soluble in mineral spirit have recently come on the market; these are probably of the acrylic type. The fact that the majority of the most permanent synthetic resins are soluble only in powerful solvents such as acetone has been one of the greatest deterrents to their application to traditional methods. When synthetic resins, either clear or in transparent and opaque colours, are used in their solid forms as material to mould or work into shapes, they are known as plastics. These materials have recently been considered for use by sculptors, and some experimental work has been done with them.

Oleoresins or Balsams

The thick, viscous liquids which exude from certain trees, mainly conifers, are called oleoresins or balsams. They are non-miscible with water, but are miscible with the oils and solvents commonly used in paints and varnishes. While the best of them may be incorporated into liquids which will dry to form hard films when spread out thinly, they will not readily harden in their original state, but will remain liquid indefinitely when kept in closed containers.

The nomenclature of these products, some of which are called turpentines, is explained under *Turpentine* on page 264. The designation oleoresins may be slightly misleading; the liquid ingredients of these materials are entirely volatile, like turpentine, and are not fixed oils such as linseed or the other drying oils.

The various grades and types of crude and refined natural products have highly individual characteristics. Although the sources from which they are obtained may be closely related, and although from the viewpoint of general classification they may be very similar, variants of natural products are usually limited to specific purposes. This is common knowledge in the case of such materials as tobacco, coffee, grains, animal products, and earth colours, where minute differences in chemical composition, in local climatic conditions, or in species will result in marked differences in grade. The natural resins, oils, and balsams are no exception to the rule, and the various exudations of the pine family differ in their properties as much as do the more familiar products of forest, mine, and farm.

Gum Thus. The exudation from the American turpentine pines of the southeastern states, which are principally the long-leaf yellow pine, *Pinus palustris.* It is also obtained from the Cuban pine, *Pinus caribaea*, and the

* See Ives, H. E., and Clarke, W. J., *Technical Studies,*[110] Vol. IV, 1935, pp. 36–41.

loblolly pine, *Pinus taeda*. It is not used in artistic painting, as it is much inferior to the two products next listed. It is the source of turpentine and rosin; its defects are similar to those of rosin.

Venice Turpentine. Exudation from the Austrian larch, *Larix decidua*. A heavy, thick, resinous liquid which has a characteristic odour combining those of pine wood and pine needle. It has a long history and has been used extensively by artists in glaze mediums, varnishes, adhesives, and plastics.

Strasburg Turpentine (*Olio d'Abezzo*). Exudation from the silver fir of the Tyrol, *Abies pectinata*. A product very similar to Venice turpentine. Seventeenth-century compilers of recipes were unanimous in preferring Strasburg turpentine.

According to Barry,[81] Strasburg turpentine was widely used during the sixteenth century and was preferred to Venice turpentine on account of its better colour and odour. Venice turpentine became of great commercial importance about the middle of the eighteenth century. Neither of these products has had much industrial importance for some time. They are valuable in painting mediums because they have the property of drying into desirable films when mixed with drying oils, etc., because they enter into stable emulsions with the accepted constituents of tempera mediums, because, compared with the customary oils and varnishes, they are acceptably permanent, non-yellowing, and durable, and because they tend to impart more flexibility and life to the films than do most resins. When Venice or Strasburg turpentine is mixed with stand oil, the resulting varnish is superior for artists' mediums to the cooked oil-resin varnish group; and when liquid driers are added, the resulting product is superior to those varnishes into which driers have been cooked.

Burgundy Turpentine. Obtained from *Pinus maritimus*, the tree which is the source of the French turpentine and rosin industry. A slightly purified and solidified grade known as Burgundy pitch is sometimes obtainable; it is called for in some antiquated recipes, principally in medicine; it has no value in painting mediums and few properties for technical uses that cannot be duplicated by the two products just mentioned.

Jura Turpentine. Exudation from the red pine of the Vosges, *Picea vulgaris*. Apparently very similar to the above.

Canada Balsam. Obtained from the familiar balsam fir, *Abies balsamea*, of the eastern United States and Canada. Widely available in clean grades, as it has some commercial importance as an adhesive used in various industries. Because the tree from which Strasburg turpentine is gathered is said to be very similar to the American balsam, this domestic material has often been suggested as a possible substitute for Venice and Strasburg turpentines, but little work on adapting it to such uses has been published.

Copaiba Balsam. An exudation from a South American tree. The product comes in a number of variations bearing the names of localities, and some publications describe details of the many grades available on the European market. For practical purposes there is probably very little difference between

them. The reliable supply houses select this material mainly for the properties which make it valuable in the few limited uses mentioned here and under *Conservation*, regardless of source or variety. Most of what is imported here is known either as Para (from Brazil) or Maracaibo (from Venezuela). In general, the Para contains more volatile and less solid ingredients. All varieties have the same characteristic odour.

Copaiba balsam is a very slow-drying material and has poor properties as an ingredient in painting mediums or emulsions; it should never be used for such purposes. When it is diluted with at least an equal amount of turpentine to a free flowing consistency, it may be rubbed or brushed over dried oil films in very thin layers, where it has the property of bringing out the full tones of dry, sunken-in colour and is said to combine with or penetrate slightly into the surface of the film. When so applied it can be overpainted or varnished with any of the accepted oil painting materials, without any apparent harm to the picture. It is even popularly supposed to be beneficial to the life of the film, acting as a plasticizer or, in the case of old, brittle films, as a regenerator, but its value in these respects is probably overrated. It is employed in several details of restoring technique, but is of doubtful value for general use by the painter. Most proprietary regeneration and restoring nostrums employ it as an important ingredient.

Flat or Mat Varnishes

A flat- or mat-finish varnish is produced by adding a flatting material to a varnish of the type needed in any particular instance. The most successful flat varnishes are those produced for industrial use—the cooked oil-resin, long oil type, such as spar varnish. Flat picture varnishes are much more difficult to make. All flat varnishes have an opaque, cloudy appearance in the container, and require thorough stirring before use.

As noted on pages 99 and 130, a flat finish is one whose surface is microscopically rough and irregular as compared with the smooth, glassy nature of a gloss finish.

The rough surface may be secured by the use of wax or wax-like materials which, as noted elsewhere, retain their definite semi-crystalline structure when dissolved or suspended in oils and varnishes. Another and older method is to introduce a finely divided inert pigment such as magnesium carbonate (light) which, besides being translucent and almost transparent in oils and varnishes, will tend to produce this rough or mat effect. This material is ordinarily used only to produce a non-transparent but translucent coating, such as an imitation of ground glass for windows, etc., but it sometimes may be added in very small amounts to a wax-finish varnish to improve its flat quality, usually at the expense of some of its transparency. The antiquated method of applying milk or buttermilk to the surface of a painting simply coats and obscures it with a thin film of impure casein and butter fat, and it is not to be recommended. It is sometimes used for a temporary effect, since the film is easily removed with a damp cloth. On oil or resin surfaces of any

delicacy, however, such materials must be cautiously tested, for they are quite likely to cause permanent blemishes by faintly attacking the surface, particularly when they form drops or runs.

Wax will make an oil varnish flat, and to a less satisfactory extent will reduce the gloss of a simple-solution resin varnish, but the dried films will be tender and susceptible to polishing. A typical recipe is four ounces of molten wax, preferably white beeswax, thinned with ten fluid ounces of damar varnish (5 pound cut) and two fluid ounces of turpentine. Most waxy flatting agents must be used in approximately the same proportions, and for best results the waxy material should be used in amounts just sufficient to produce the desired effect. It is usually necessary to alter formulas for this type of material by making trials, in order to obtain the best results in each case.

Aluminium stearate, a bulky, waxy substance which is mentioned under *Stabilizers*, is a better material for this purpose, and it gives very satisfactory results when used in a long oil varnish. With a simple solution of damar or mastic, however, or even with a short oil industrial varnish, the mat effect is not always so well produced, and is easily destroyed by such light rubbing as ordinary cleaning or dusting with a cloth. Wax is employed in furniture polishes because its particles have the property of coalescing and forming a smooth, lustrous, continuous surface when friction is applied; most of these mat varnishes tend to act like wax polishes when rubbed.

A gelatinous material known as zinc tungate produces the best flat varnish results when expertly combined with damar; it consists of zinc oxide expertly cooked with tung oil. When it is combined with the correct amount of damar varnish and turpentine, non-polishing flat varnishes of satisfactory toughness, transparency, and permanence of finish are obtained. But although it has been accepted by many expert restorers and museums, and seems to be thoroughly sound in most respects, there is some suspicion that it eventually yellows and becomes rather difficult to remove. It is a very rapid drier; its colour in the bottle is quite yellow, and it has a waxy turbidity.

Until further improvements and complete ageing tests have been made, it would seem best to use all such materials sparingly and only when a flat finish is absolutely requisite, and to continue with the time-tested clear damar and mastic as much as possible, especially in the case of recent works of permanent artistic value. Semi-mat or satin finishes may be obtained by mixing clear and flat damar varnishes in various proportions. A flat finish takes better on a pale or 'blond' painting than on a dark or deep-toned one; considerable black or near-black areas, such as those in many old portraits, are liable to be made grayish or streaky by the mat finish. Many paintings, particularly dark ones and those with very rough or impasto surfaces, require a varnish with a bright gloss to bring out their full values.

As mentioned previously, a dead mat quality is not a natural characteristic of the oil painting technique and any method used to obtain it entails a deliberate sacrifice of some good quality—durability, non-yellowing, etc.

Inspection of Oils and Varnishes

When oils or other transparent liquids are examined to determine their colour in the liquid state, the *volume* of liquid which is being observed must be considered, and all comparisons are inaccurate unless the samples are viewed side by side against the light in bottles or tubes of exactly the same dimensions.

An oil or varnish of heavy consistency will naturally be darker than the same kind of product with turpentine or other solvent added. An approximate method for comparing the viscosity of heavy oils and varnishes is to fill two identical tall bottles to the same level (nearly full) with the materials to be compared. Cork tightly and invert suddenly at the same time. If the materials are heavy enough for the bubbles to travel slowly, any difference in consistency will be apparent from the relative speed with which the bubbles rise. Experienced persons can judge approximate consistency and body* by dipping a palette knife into the liquid and allowing it to flow off the blade at an angle of about 45 degrees. For more accurate measurement of density, the hydrometer (page 425) is simple and easy to use. These are simple tests for the guidance of users of oils and varnishes; data of absolute accuracy in these and other tests can be obtained only by skilled technicians. The artist may easily test the comparative yellowing of oils and varnish films by methods noted in the section on the testing of pigments. An accelerated yellowing test may also be made by coating a piece of white canvas with the clear oil or varnish and allowing it to remain in a dark box or cupboard face down over an open container of water. If the box can be kept warm, the test will be more severe. Materials which contain drying oils will yellow rapidly when allowed to dry in a humid atmosphere without daylight.

Poppy oil colours can usually be distinguished from those made with linseed oil by their lack of odour, though old samples may become somewhat rancid.

Adulterants in Varnishes. Rosin, which is probably the cheapest substance used as a paint material, is the most common adulterant in all types of varnish.

Simple-solution varnishes intended for general industrial use are often 'improved' by the addition of linseed, tung, or castor oils, copal varnish, etc., to give special qualities. For artists' use, such products must be considered adulterated, and only varnishes made by reputable artists' material specialists or at home from pure resins, should be used.

Driers

In order to accelerate the drying of mixed house paints, varnishes, and other compounds of drying or semi-drying oils, reactive materials are added

* The term body when applied to oils, varnishes, and other mediums for paint purposes, means a little more than just the consistency or thickness; good body implies a certain optimum direct relation between the degree of viscosity and the specific gravity, as in the case of raw linseed oil or a conventional standard varnish. A medium which has a thick-flowing consistency unaccompanied by the proportional heavy weight to which users have become accustomed—in other words, one which has high viscosity and relatively low specific gravity—is said to possess *false body*.

which have the power of starting, accelerating, or forcing the absorption of oxygen by the paint film, or of overcoming conditions which inhibit drying.

Driers or siccatives are metallic salts combined with materials such as oils or resins which mix with the usual paint and varnish ingredients. They are diluted with solvents for convenience in using. Their chemical and physical reactions are not fully established (see page 314).

As a general rule, driers detract from the life of paint and varnish films and are to be considered undesirable additions to oil paints and varnishes for permanent painting, especially when used indiscriminately. However, when sparingly applied with judgment by experienced painters, a good drier can be used with safety, and in some instances, as in glaze manipulations, may be essential. Driers have been in use as long as drying oils.

Some pigments act as driers; the rapid driers are listed on page 119 in the order of the accelerating effect they exert on drying oils. Whenever a drier is desired, these pigments will act in that capacity with no bad results, provided they fit into the desired colour effect.

The most common driers available to artists in the recent past have been siccatif de Haarlem and siccatif de Courtrai. These materials contain lead and manganese resinates cooked in oil. Practically every one of their ingredients has the property of turning dark eventually. Furthermore, they are progressive driers; that is, a pronounced action continues long after the film has dried to the touch. This leads to brittleness and cracking.

Inasmuch as the oils and resins take up a very small percentage of metallic salts, driers are composed largely of inert materials. Only a comparatively minute amount of active drying ingredient is required to give a strong siccative effect.

Cobalt linoleate, which is made by cooking cobalt salts in linseed oil, is the best (or rather least harmful) drier for permanent painting. It is less progressive than other driers—that is, it seems to act mainly while it is still in a liquid state—and less likely to cause excessive darkening with age.

The earliest use of cobalt driers I have been able to trace was in France in 1852, when products identical with materials in use today were described*; so far as I know, the earliest American reference[68] to the same materials was in 1874, but they were not widely used in America until the early days of the twentieth century, probably because they were not believed sufficiently superior to the manganese driers to warrant their higher cost. They were thoroughly approved and adopted throughout the paint industry long before they became artists' materials; in fact, the traditional siccatif de Haarlem and siccatif de Courtrai survive to this day, although most authorities condemn them.

Driers must not be used in thick, pasty painting nor in underpainting. Ostwald[29] says that a thick painting done with lavish use of driers is 'an old man on the surface while it is still a youth within', the drying action being more rapid on the surface where the painting is in contact with air.

Driers are of value mainly in glazes and thinly painted pictures where

* *Description des Brevets d'Invention*, vol. 24 (2e série), p. 319.

the entire mass of paint can dry thoroughly in a short time. Such pictures may receive a thin final coat of protective varnish, applied soon after the painting is, in the opinion of the painter, thoroughly dry, instead of several months later, as is customary when no driers are used.

The most important rule to observe in adding siccatives to glazes or painting mediums is to test the drying action of the mixture before using it. Mix one of the pigments of average drying properties (page 119) with some of the medium to which the drier has been added, noting for future guidance the number of drops of drier to an ounce of medium. Paint it out under exactly the same conditions which will attend its later use, and allow it to dry overnight or for a longer time if desired. After this, regulate the amount of drier so that just enough is used to produce the required siccative effect, the object of the test being to keep the amount at a minimum. The figure will be an approximate guide for future use; it varies according to the humidity and temperature in different seasons of the year and is different with materials from different sources.

The addition of drier to prepared, ready-made liquid painting mediums often leads to cracking and other failures, because these mediums usually contain driers, copal varnish (which is always made with drier), and other materials which are not compatible with the siccatives added by the artist.

Driers were used by the ancients. Litharge made by roasting lead ore was described by Dioscorides, Pliny, and Galen; white lead was described by Galen and others. During the fifteenth century, white vitriol (zinc sulphate) was employed, but because zinc is not a drier it is generally believed that its drying action was due to manganese which probably occurred in it as an impurity. In Spain and Italy, during the sixteenth and seventeenth centuries, verdigris was in common use as a drier for oil, and the Spanish masters considered it the best of all driers. All the thin glazes of the early masters of oil painting seem to contain metallic driers.

As the records and instructions for the use of drying oils increase in medieval times, we find many new substances listed, so that by the time oil painting was adopted a number of driers were available for use. These driers were dissolved in the oil medium during the cooking process, as in the case of most factory-made oil mediums today. However, according to various investigations which have been made, if driers must be used, the advantages of adding them in liquid form to the finished paint or varnish are numerous: one may control the amount more accurately and hold it to the minimum required for the purpose, thereby prolonging the life of the film; the instability of some mixtures or oils and driers on storage is obviated by adding the drier as required. It is also my own opinion from observation and experience that films so produced seem to be less likely to crack or turn yellow than those whose oil contains drier cooked into it.

Poppy oil is best excluded from the list of glazing materials and from mixtures which contain driers because of its tendency to crack when mixed with reactive substances and because its range of safe uses is limited, extending little beyond the simplest manipulations of ordinary direct oil painting.

DRIERS

A very small percentage of active metallic ingredient is present in the most concentrated prepared liquid driers. For example, the powerful, concentrated cobalt linoleate contains 3 to 6%, depending on its form; any usable liquid would contain 4% at the most; the commercial product put up for artists' use probably contains considerably less. The rest of the contents in the case of pure cobalt linoleate is linseed oil and thinners; in other commercial liquid driers it is likely to be almost any compound of oils, resin, or synthetic materials. Prepared driers are useless to manufacturers of industrial paints unless their exact metallic content is given. The material referred to as cobalt linoleate drier in this book is made by mixing 2½ fluid ounces of turpentine or mineral spirit with 8 fluid ounces of the syrupy 6% pure cobalt linoleate.

As noted on page 119, many of the artists' oil colours on the market contain driers, and some of them may contain materials which retard the normal drying action of certain pigments. If the user of home-made colours finds that a drier is necessary to bring the drying rate of a certain colour closer to the average rate of the rest of his palette, it should be added in the same cautious manner recommended above in the case of glaze mediums. The aim should be to improve the pigment's drying rate to an acceptable degree, not necessarily to make it equal to that of the rapidly drying pigments.

Glazes and Glazing

Glazes are mixtures of mediums and transparent pigments which are applied over dried oil or tempera underpaintings. The colour of the undercoat blends with that of the transparent glaze; because it is not mixed with it as in direct oil or body-colour painting, the nature of the resulting colour or optical effect differs from that of body-colour and may be more or less identified with the second system of colour blending mentioned on page 33. A rough illustration is the effect obtained by superimposing a sheet of coloured celluloid over another colour.

Minute amounts of opaque or semi-opaque pigments are often added to transparent glazes, the slight thickness of the film allowing the colour of the underpainting to be effective. They are also added in order to tone down overbrilliance or to rectify lack of solidity.

Requirements for a Glaze Medium. 1. It must brush out well and allow the desired manipulations to be carried out easily. For this requirement it should be neither too oily nor too tacky, but balanced according to the preferences of the user.

2. It must be composed of time-tested, permanent materials.

3. It should dry within a convenient length of time. Overnight is generally considered desirable.

4. It should not exert a solvent action upon or pick up the underpainting.

5. It should resist the solvent action of subsequent coats of glaze or varnish.

6. It should not run down or flow when applied in a reasonably skilled manner to a painting in a vertical position, as on an easel. However, the

more precise glazing manipulations are usually carried out with the picture in a horizontal position.

From the foregoing, it will be seen that no single oil or varnish meets the specifications and that carefully balanced mixtures must be used.

Many prepared painting mediums are sold, but few are to be recommended to careful artists, as the composition of such products is seldom made public. When these mediums require additions to adjust their properties, it is impossible to foresee the result as regards permanence; some of them are made according to antiquated formulas which contain miscellaneous unstable ingredients such as lead and manganese driers, copal or rosin varnishes, raw or oxidized oil, and synthetic resins.

Scumbling is a somewhat vague term usually applied to the rather wholesale daubing of an entire painting or considerable areas of it with a thin coating of colour in any medium, while the term glazing always implies carefully controlled placing of a thin transparent layer of more definite composition. Scumbling is done over a coat of paint which has become dry to the touch or over an isolating varnish, with either glaze medium or straight oil colour, opaque or transparent. The paint may be applied with a brush and the surplus wiped off with a rag, leaving a uniform coating of the desired tone, or it may be stippled or rubbed on with a brush, dauber, rag, or with the fingers.

Manipulations. Glazing may be done by applying thin, transparent paint with the brush, by stippling the colour on with the tip of a more or less blunt brush, by using a blender or badger hair brush, or by use of a pad, tampon, or dauber. Choice of method of application depends entirely upon the artists' painting technique and the type of effect he desires. For very clean, unbroken, mechanically perfect results, a different handling is naturally required than for more casual effects. Most of the remarks in this section are made with the more smooth, perfectly blended type of picture in view; their application to freer or more casual use is a simple matter, and the average painter who employs glaze methods in a looser technique may extract from the complete method such points as are useful in his work.

Large areas in which tones are imperceptibly graduated from light to dark or from one hue to another, such as skies, plain backgrounds, etc., are best glazed by carefully mixing each colour before beginning. If the glaze medium contains driers, one must work with dispatch; otherwise the material will begin to set before it is used. In most instances there is ample time to apply it if there is no unnecessary delay.

Care must be taken to make the colour mixtures smooth, homogeneous, and free from particles of paint skin, lint, or other impurities. Saucers are convenient to use; the material may also be poured into screw-cap jars if desired. Usually a beginner will find that about twice the expected number of separate tones or shades are required to obtain a smooth gradation of colours. The consistency may vary from that of a heavy flowing syrup to that of a thin varnish body, according to preferences and requirements. Blendings between two colours must ordinarily be made before the first one has set, the two wet

glazes being worked into each other. Sometimes for pictorial reasons the lighter shade is best worked into the darker, or vice versa, but if one (usually the darker) contains more liquid and less pigment than the other it is likely to have more picking-up tendency because of its greater solvent action; therefore, unless other considerations are more important, the darker colour is best applied first in blendings.

It will be found impossible to create clean edges around an unglazed area if the glaze is allowed to run over the edge and then is wiped off with turpentine, for the solvent will run back into the glaze and destroy the edge. If the nature of the work is such that the glaze cannot be wiped off sufficiently clean with dry cotton or cloth, edges are best glazed by the precise use of fine brushes.

If daubers or tampons are used, they may be made entirely of cheesecloth, care being taken to fold it so that a flat, unwrinkled surface is produced; or cheesecloth may be filled with absorbent cotton. Well-washed or old cotton sheeting, silk, fine or coarse cloth, knitted or stocking material, leather —any one of a number of materials may be used, each producing a different effect. The dauber should be lightly loaded with paint, which should be applied by tapping or pouncing only, not by smearing. A separate brush or tampon must be ready for each colour, and the brushes must be perfectly dry; they cannot be used long before they become too full of paint for further use. I find that a convenient way of quickly cleaning and drying a brush for this use is to rinse it in turpentine, wipe it off, then remove the slow-drying turpentine by rinsing the brush in a cup of ethyl acetate, acetone, or other rapidly evaporating solvent. If the brush is again wiped off and its handle twirled between the palms or flicked on a cloth, it will dry at once. This procedure is useful in other methods of painting as well as in stippling glazes. Small areas, naturally, must be glazed only with brushes; stippling and blending with various types of brushes will give various surface effects.

The general rules are to keep the glazes thin, to apply darker tones over lighter, and to apply several thin coats rather than one heavy one.

One danger in overreliance upon smooth glazing is that glaze effects in the general run of artistic painting are likely to lead to undesirable halftones, lack of forcefulness, or mechanical textures, especially if they are overdone. These, however, are not strictly technical points, but rather matters for the individual painter's consideration. Glazing should be intelligently used as a tool or instrument; when so employed, no sound objection can be made to it on technical or optical grounds. Although the separation of layers of different colour coats will produce a certain luminosity of tone, especially when painted over a white ground, the finished painting in which glazes have been used will absorb a great amount of light, and it is best exhibited in a very well-lighted position.

Formulation of Glaze Mediums. Because the film of glaze is so thin, a little more latitude in the selection of its raw materials is allowed than in the case of body-colour paints, and well-selected driers and varnishes may be

mixed with oil. These materials themselves, however, must be of the very highest quality and not liable to turn yellow with age.

In the formulation of a glazing liquid to be applied either to recently dried or rather well-dried layers of oil or tempera paint, consideration must be given to the rule of gradation of coats, as explained in the section on *Painting in Oil*. The glaze film should not be coarser in physical structure or less flexible than the underlying layers, and the properties of the materials which compose it should not be too foreign to those contained in the undercoat. In a glaze, the proportion of fixed oils to pigment is ordinarily greater than in the case of a body colour. Good working qualities and the exclusion of materials which may yellow or promote yellowing are also considerations, and careful attention to the balance of solubility is most important.

A useful glaze medium for general all-round purposes contains one fluid ounce each of stand oil and rather heavier-than-average damar varnish. If damar of the regular consistency is used, about 1¼ ounces should be mixed with one ounce of stand oil, but the proportion may be varied freely to suit the preferences and requirements of the user. Less varnish will make the medium more oily; more varnish will make it tackier. From five to seven ounces of turpentine are then added according to the requirements of the user, six being about the average. In order to make this medium dry conveniently, about ¼ teaspoon of cobalt linoleate drier is stirred in. In order to employ a minimum of drier it is best not to adhere to any set quantity, but to test the amount required each time by the method described on page 158. Whenever the medium is used pour the liquid off without disturbing any sediment which may have formed. Mediums containing liquid driers should not be expected to keep for more than a few months without some disintegration. This medium is designed to be used with tube oil colours, either as they come from the tube or after they have been spread out on bond paper for a while to remove some of the surplus oil. It works well in the glazing of oil paintings, and also in glazing gum tempera of the type for which a formula is given in the section on tempera painting, because it contains the same ingredients. An example of a variation of this medium is a retouch varnish which may be made of the same ingredients by mixing them in the following proportions and order.

By volume:

5 ounces damar varnish (5 lb. cut)
1 ounce stand oil
½ ounce toluol
½ ounce anhydrous alcohol. Stir or shake until clear and add
13 ounces turpentine

The use of retouch varnish is mentioned on page 132. Although this varnish is acceptably non-yellowing, the well-known Vibert varnish is equal if not superior to it in non-yellowing properties, by accelerated test. The current Vibert brand contains 75% of volatile solvent (a highly refined petroleum spirit), and 25% of a clear resin which by test shows no trace of

damar or pine resins. It is probably a synthetic resin. Some of the present-day retouch mediums are simple solutions of synthetic resins and plasticizers in special or highly refined solvents. Such mediums can be thinned with turpentine or its petroleum substitute and used successfully in very thin coatings as retouch varnishes, but so far they have not been successfully applied in any other paint or varnish techniques.

According to Church,[30] Bell's medium contains blown linseed oil thinned with spike oil, and Roberson's medium may be duplicated with a mixture of copal varnish, poppy oil, and white wax.

Another glaze or painting medium in use by a number of American painters consists of a mixture of

9 parts damar varnish (5 lb. cut)
9 parts turpentine
4 parts stand oil
2 parts Venice turpentine

This material is preferred to the first recipe for use on egg/oil tempera. It may be utilized for the dilution of tube oil colours or for the grinding of dry pigments. For use in the so-called mixed technique, careful painters add a drop or two more of stand oil when mixing colours for overpainting, in order to insure the greater flexibility of the layer as compared with the one which lies beneath.

Sun-thickened oil has long been a favourite ingredient in glaze mediums because it has a rapid drying rate. One recipe is

4 parts damar varnish (5 lb. cut)
2 parts sun-thickened linseed oil
1 part Venice turpentine
4 parts turpentine

An advantage of this medium over the damar-stand oil mixture is the absence of drier; sun-thickened oil dries with great rapidity, but in some climates and with some pigments a few drops of drier may be found necessary. Comparative tests over a number of years, however, show that the damar-stand oil medium is at least its equal in non-yellowing, and that it may be applied to a greater number of uses without failure. The combination of sun-thickened linseed oil and Venice turpentine is best suited for use in glazing egg/oil emulsions, and in general gives good results when dry colours are ground directly in it. Additional turpentine should be added according to the judgment of the user to compensate for the evaporation during such grinding, and when the resulting paint is used in successive coatings each upper layer may be made more flexible by the addition of a drop or so of sun-thickened oil.

The above two mixtures are not recommended for glazing gum tempera or straight casein paints; their adhesion, range of expansion and contraction, etc., are not so suitable for these uses as the corresponding qualities of the damar-stand oil mixture; on the other hand, that mixture is perhaps less suitable for use in the egg/oil tempera techniques.

Straight egg tempera may be, and often was in the earlier days, glazed with dry colours ground in diluted egg-yolk. This procedure is followed by some tempera painters today and its results are quite luminous and high in key. Some practice and experiment is necessary to control this procedure; the usual technical danger, as with all pure egg-yolk techniques, is that the inexperienced painter will not dilute his paint with enough water. An objection on optical grounds to such entirely pure egg-yolk techniques is that the results are likely to be thin, unsubstantial, or water-colourish. This, however, is more often the fault of handling or manipulation than of any inherent defect in the process. Some painters desire this quality and do not consider it to be a fault.

The mixture of linseed oils of various degrees of refinement is a procedure of considerable antiquity; it was adopted by craftsmen of the past who, although they would have been at a loss to explain the reason, were very well aware of the fact that such mixtures had properties entirely different from those of a single oil refined to approximately the same viscosity, colour, and body (see page 312). A small amount of a linseed oil of ordinary consistency added to stand oil will impart a certain hardness, body, or solidity approaching that produced by a resin; some of the old effects which may be approximated by the use of Venice turpentine and oxidized oil may also be duplicated by the above mixture, particularly as regards manipulations and brush stroking. Oxidized oils will impart a still harder or more brittle nature to stand oil. The prepared painting mediums on the market, particularly the older brands which originated in times when practical industrial varnish makers were constantly formulating and producing such mixtures, probably contain more than one type of linseed oil. It would of course be impossible for a chemist to duplicate such formulas by purely analytical means.

One of the principal differences between a glaze medium and a picture varnish is that the latter must be easily removable by a simple solvent which does not act on the painting, whereas the glaze film must be capable of resisting the action of cleansing and picture varnish solvents.

Should it become necessary or desirable to remove glazes and overpaintings without disturbing the underpainting, this can usually be accomplished by various means, depending upon the nature and age of the paint. Films of any appreciable thickness are best removed by gentle scraping with sharp blades as described on page 348; if an isolating varnish has been used, the procedure is easier. Oil glazes and overpaintings on tempera pictures are rather easily removed by this method; they can also be taken off with acetone or certain other solvents if these are applied by careful picture-restoring methods. Very slight or delicate oil glazes of recent application can often be removed or taken down with Artgum or other mild abrasive.

4

Tempera Painting

In the modern usage of the term, tempera painting is painting that employs a medium which may be freely diluted with water but which upon drying becomes sufficiently insoluble to allow overpainting with more tempera or with oil and varnish mediums. Remarks on the derivation of the word tempera will be found under temper on page 435. Tempera paintings are best executed on rigid panels coated with absorbent gesso, but sometimes the less desirable canvas is used as a support.

Tempera paintings are characterized by a brilliant, luminous crispness which is never exactly duplicated by the use of oil or other mediums. Although its materials are applied in many distinct variations of technique, tempera paintings may usually be identified as such without much doubt. When left unglazed they have a pleasing flat or faintly gloss finish. When carefully glazed and worked up, they are capable of presenting a highly developed appearance.

In tempera the fourth or optical function of the medium (see page 106) scarcely exists, and when the paint is dry the colours resemble their original dry state more than do the deep-toned oil colours. Depth of tone, if desired, must be brought out by a final application of varnish or transparent glazes.

This separation of the optical properties from the mechanical properties of the medium is not to be considered a complete disadvantage, because it contributes largely to the tempera effect and allows a controllable, systematic method of working which appeals to many painters.

The dried paint film does not become yellow or darken with age as faulty oil paintings may do, because the medium itself is non-yellowing compared with oil, and there is considerably less excess of binder in the finished painting. The bulk of the liquid (water) evaporates completely from the film.

Many of the conditions which cause cracking and other failures in oil painting are not present in tempera. Correctly painted tempera pictures are less likely to crack with age than are oil paintings; if there has been any fault in the preparation or execution of the painting or ground which might result in cracking or other failure, such failure will almost certainly show up soon after the picture is dry. This is a general statement to which there are occasional exceptions, but it is fairly safe to assume that if a tempera picture has not exhibited traces of cracking by the time it has become thoroughly dry, it will not crack at a later date.

However, tempera mediums are not fool-proof; if improperly formulated

or applied, they may be subject to as many defects as oil mediums. As a general rule, the tempera techniques are not well suited to casual attempts at painting and for the most part require serious consideration and a familiarity gained through intelligent understanding of their principles. Tempera paintings of extreme age (several hundred years old), especially those on canvas, are very often covered with a characteristic allover crackle of small size, which ordinarily has no effect on the adhesion of the paint and is seldom visible except on close examination. When oil or varnish glazes are applied over tempera, they are subject to the same rules that govern glazes on oil paintings, and, as in the latter medium, if they are improperly selected or applied they will exhibit defects such as cracking or darkening with age; however, the tempera foundation is perhaps more suitable than oil for receiving such thin films, and the entire paint structure is less subject to decay.

When compared with oil painting tempera has certain limitations and disadvantages as well as the advantages just listed. It is more limited in its range of effects, and the inflexibility of its film makes it less suitable for painting on canvas, although aged tempera films are not greatly inferior in flexibility to very old oil films. The chief manipulative advantages of oil over tempera are its greater fluidity, the ease with which its colours may be gradated or blended, its conveniently slow rate of drying, and the absence of colour change caused by evaporation of the medium on drying. Oil is a more convenient, flexible, and available technique.

Tempera Mediums

Tempera mediums owe their distinctive characteristics to the fact that they are emulsions. An emulsion is a stable mixture of an aqueous liquid with an oily, fatty, waxy, or resinous substance. Milk is an example of an emulsion, the butter-fat which is suspended in minute drops being the water-insoluble ingredient. Tempera emulsions dry to form transparent films; their milky appearance when wet is caused by the refraction and dispersion of light from the countless tiny globules of oil, in the manner described under *Colour*.

The principal early type of tempera emulsion was a natural one—pure egg-yolk. The yolks of hen's eggs contain a water solution of a gummy substance, albumen, a non-drying oil called egg-oil, and lecithin, a lipoid or fat-like substance which is one of nature's most efficient emulsifiers or stabilizers. Albumen itself is a good emulsifier. The subject of emulsions is dealt with further in both parts of the section on *Chemistry*.

Egg-yolk is an example of a paint medium which contains a non-drying or semi-drying substance mixed with a quick-drying substance, the whole mixture drying successfully. There are also other instances where varying amounts of non-drying or semi-drying substances may be added to a paint or varnish whose drying properties are strong enough to carry it along, in order to impart favourable properties to the product.

Albumen belongs to a class of proteins which have the property of being coagulated by heat, as demonstrated by a cooked egg. The same effect is obtained when it is diluted, spread out in a thin layer, and exposed to daylight. The pure egg-yolk film becomes adequately insoluble, tough, leathery, and permanent, and as a film it serves as a standard by which to judge the artificial tempera emulsions. Artificial or compounded tempera emulsions are employed more for their improved executive or working properties than for any superiority in the quality of their films.

Tempera paintings are called insoluble here and in other descriptions, but this does not mean that they are absolutely water-proof or scrubbable; they may often be softened or disturbed enough by the deliberate or accidental application of water to ruin their effects. Well-dried tempera paintings may usually be cleaned with a little acetone or anhydrous alcohol if these are applied very cautiously as in the regular restoring technique. Tempera and gesso can be completely and quickly removed from panels by rubbing with soap or ammonia solutions.

They are insoluble to the extent that they are not picked up by overpainting, and when completely dry they are adequately water-resistant under all normal conditions. Neither tempera nor gesso is intended to withstand such treatment as harsh scrubbing with a bristle brush or careless application of water. Only a very slight disturbance of the colour effect is enough to ruin an artistic painting even though the paint film may be virtually unaffected from a mechanical viewpoint.

When thoroughly dry, most tempera paints will assume a satiny semi-gloss if polished with a soft cloth or wad of absorbent cotton. This is done by some painters before applying oil or varnish glazes, especially in the case of gum tempera, on the theory that such surfaces will be more resistant or more uniformly absorbent to the superimposed mediums.

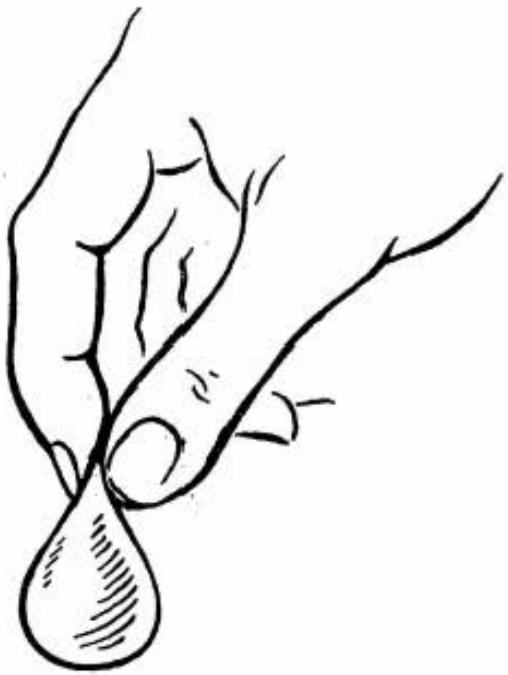
The choice of pigments which shall underlie each other is not important in tempera painting as it is in oil where their variations in oil absorption and reactivity are factors, but the rule of gradation of layers still holds—that is, no coat should be less flexible than its underlying coat. A similar general rule to be followed in the case of aqueous mediums, is that no coat should have appreciably stronger binding or adhesive power than the layer under it. Should this be the condition, the contraction of the stronger layer is liable to cause it to crack away and to pull off the weaker layer. When this occurs, it usually takes place at the time of drying or shortly thereafter at the first appreciable climatic change, as mentioned under the application of gesso.

The term *oily ingredient* as used in the discussion of tempera emulsions refers to any of the non-aqueous ingredients whether or not any oil is present, and includes waxes, resins, varnishes, and oils. The varnishes or solutions of oily materials may contain turpentine or its petroleum substitute but not alcohol, which may be incompatible with the aqueous ingredients used in tempera emulsions.

Painting with Egg-Yolk

A number of instructions for the use of egg tempera have come down to us from all periods of European art. The traditional pure egg-yolk technique proceeds in the following way.

The yolk is first separated from the white. Some painters are extremely careful to keep it free from any traces of white; others are less particular; but a pure yolk, free from white, is the standard material. The white is practically pure albumen and water, and there is enough albumen in the yolk alone for a well-balanced tempera emulsion. An excess would not injure the dried tempera film so much as it would increase the speed of drying and cause difficulties in manipulations or brushing. After the yolk has been separated from the white by the usual method of pouring it back and forth in the half



shells, or better, by the use of an aluminium egg-separator, it is held in the flat (not cupped) palm of the right hand, picked up by the thumb and forefinger of the left gently, so as not to break the skin, and suspended over a jar or cup. The skin is then punctured at the bottom by stabbing it with a knife or other sharp point, and, if desired, after most of the yolk has flowed out the little that remains can be squeezed from the skin on the slab with a finger. If, before it is punctured, the yolk is rolled from one hand to the other, the hands being alternately wiped on a towel or apron, until the skin of the yolk is dry, a further removal of traces of the white is effected. Sometimes painters merely break the eggs into a coarse strainer, and after the white has drained off, puncture the yolks and allow them to run into a container. If this is done it is well to strain the yolk again through muslin, but the result will not be so pure a yolk as that separated with greater care.

The pigments are well ground in distilled water with the muller, and

placed in small screw-cap jars where they will keep indefinitely. Just prior to use, an equal volume of this colour paste (about the consistency of tube oil colours) and egg-yolk are mixed. Some painters add a little water to the egg —$\frac{1}{6}$ to $\frac{1}{3}$ of the volume. A set of kitchen measuring spoons is handy to use in measuring proportional amounts of both dry and liquid substances.

There is no technical objection to grinding the colours directly into the egg or into a mixture of egg and water, which some painters prefer to do, especially with pigments that do not grind easily in water alone; but keeping them in the form of a water paste and adding the egg just prior to use ordinarily saves much labour because the colour and water paste keeps indefinitely. While the painting is being done the main supply of the egg-tempera paint may be kept in little covered jars or cups instead of on the open palette where it will harden more quickly. If these containers have no screw caps they may be covered with a damp cloth during painting operations. A piece of moistened filter- or blotting-paper inserted in the cap of a jar will produce a humidor effect and retard setting or skinning of the surface, but in warm weather will tend to encourage decomposition or mould.

Pure egg tempera is best applied to the absorbent gesso panel without previous coating; if it is desired to have the panel somewhat less absorbent, a very dilute gelatin size may be employed. Some painters, especially those who put down a very accurate and careful drawing on the gesso before painting, use the size as a fixative for their drawing. It is better not to colour the first size and use it as a veil, because of its penetration into the pure white gesso; but a coloured veil or size may be applied as a second coat. Other materials suitable for a first sizing of the gesso are very much thinned down shellac varnish, egg-water made by mixing a teaspoonful of egg yolk in a full glass (6 ounces or more) of water, and a much diluted casein size. The unsized gesso surface is, however, most desirable in the average case. Its absorption of the tempera medium is not usually sufficient to destroy its whiteness, but it is not considered advisable to use very heavy impasto strokes at first, before thinner coats of paint have reduced absorptive action. The theory is that too much absorption of binder by a ground will leave the pigment of a thick layer insufficiently bound. The gesso surface can be made less soluble by spraying it with a 4% solution of formaldehyde if desired, but this is seldom necessary. Pure egg-yolk is primarily suited for smooth painting; it is not so well adapted to heavy impasto as is gum or egg/oil tempera.

It is better not to use preservatives in egg, and most painters prefer not to use them. The egg alone or in mixture with colours will keep in a dark, cool place for three or four days; if it becomes necessary to keep it longer, a 10% phenol solution (carbolic acid) may be added in minute amounts, or 1% or less of a 3% solution of acetic acid, vinegar being the traditional egg preservative. Most vinegars contain from 3 to 5% of acetic acid. Acid solutions will attack chalk or whiting grounds, ultramarine blue, and the cadmiums. It is doubtful whether many present-day painters use acid or other preservatives in egg. The decomposition of tempera paints and similar materials can be delayed by refrigeration, but freezing will destroy their properties.

Cennini[7] refers more than once to the use of fig-tree sap, either added directly to the whole egg to make a wall size, or introduced by beating the egg with cuttings of the young shoots to produce a medium for secco painting. Every possible explanation has been offered for these procedures by various writers; fig-tree sap has been said to be a preservative, to add toughness and flexibility (the juice is similar to latex, the milky sap of the rubber tree), and to make the paint more brushable. There is no record of its use in modern times. The so-called fig-milk of German origin is an artificial product, a complete tempera emulsion in itself.

It is always advisable to use the freshest eggs obtainable; the medium will then stay in condition for the longest possible time, and the paint will be superior in every respect. Storage and preserved eggs are suspected of forming weak or impermanent films. The yolk is useless as a medium after it has commenced to decompose. The yellow colour has very little effect on the paint, especially when the yolk is well diluted with water and mixed with pigments. Daylight is said to bleach it permanently soon after it dries. Cennini recommended town eggs as being paler than country eggs; some types of white eggs have very pale yolks; but the practical difference between the lightest and the darkest is very slight.

When painting with egg, plenty of water should be used, and the brush should be dipped into water frequently. When the amount of egg is in proper relation to that of pigment, a large amount of water may be added to the paint; inexperienced painters often have difficulty in handling the tempera medium through not introducing enough water. When too much egg is used, the paint will dry too rapidly and brush out with difficulty; when not enough egg is used in relation to the amount of pigment, the resulting film will be weak and powdery. To test the paint film it should be brushed out and allowed to dry on a sheet of glass. If it can be peeled off in a continuous, tough film with a knife, there is enough egg to bind it; if it powders or flakes off there is not enough. Some pigments, as will be found by experience, require a little more egg than others. This procedure does not, however, afford a fair test of the paint film's time of drying, brushing properties, etc., because the conditions are too far removed from those of actual painting on a gesso ground.

The foregoing account is intended to be an outline of the pure or classic method of egg tempera as practised in Italy from some time before the fourteenth century until the improvements of the fifteenth century; all other tempera procedures stem from it.

Emulsions of Egg and Oil

The addition of stand oil, sun-thickened oil, Venice turpentine, and cold-pressed linseed oil of normal viscosity to egg-yolk and whole egg has been mentioned in early writings, but there is little record of the establishment of any standard, traditional technique or of any exact formulas; all recipes in present-day use are of comparatively recent origin.

EMULSIONS OF EGG AND OIL

Addition of oil to egg changes the latter's qualities, and without entirely losing its tempera character, the medium tends to acquire some of the oil characteristics. It becomes somewhat easier to handle and is more adaptable to a wider range of effects, especially when used by an artist whose training and experience have been principally confined to oils; it piles up a little more satisfactorily than pure egg-yolk; that is, sharply textured or semi-impasto strokes stay put. For really heavy impasto spots, such as those produced by the early painters in making small spots stand out in bold relief, it can be used to much better advantage than the pure egg-yolk, but still not so well as gum tempera. For the technique which paints tempera into wet oil-medium colour as described further on in this section, an egg/oil emulsion seems to be the most desirable.

Egg/oil mixtures have several disadvantages: their tendency to lean somewhat toward the oil painting characteristics sometimes brings their optical effect toward that of oil and away from the pure egg tempera appearance; the emulsions must be accurately and rather delicately balanced in order to work successfully; and their behaviour is likely to be erratic and influenced by very slight variations in conditions. Every once in a while an egg/oil emulsion refuses to dry and becomes gummy and intractable under the brush. This behaviour is usually accompanied by a separation of oil from the emulsion in rather large, visible globules and occasionally traction fissures will occur in the film. The cause of this condition is not always easy to analyse. The oil may have become separated from the emulsion because of the presence of impurities such as soluble salts; the emulsion may have gone over to the water-in-oil type which is described on page 307, the emulsion may not have been combined properly, some of the oil remaining in superficial mixture rather than being completely dispersed or emulsified, or sufficient water may not have been used. Stale eggs may also be the cause. In an egg/oil emulsion the limits within which proportions may vary are rather narrow, and not too much deviation from a successful recipe may be made.

The remarks on the defects of egg/oil emulsions are to be taken as warnings or precautions rather than as condemnations of the medium, for many painters make use of it with complete success, and its properties and effects exactly suit the technical and artistic requirements of some of our most popular current schools of painting.

Most of the published formulas for egg/oil emulsions are apparently of German origin. Perhaps the most universally successful mediums of this type are those formulated from the starting point of equal parts of whole egg and oily ingredient, to which are always added at least two parts of water. Doerner[38] says that such emulsions need not be mixed with special equipment nor for very long, and recommends only a brief shaking in a tall bottle. This is not quite in accordance with the approved methods of making stable emulsions of this type as established in scientific and industrial practice, where care is taken to agitate the mixture long enough to break the oil into globules of the smallest possible size and to make sure that none of the oil

remains unemulsified. Such mixtures are agitated by shaking them in a tall container or by stirring them with a propeller; there is some disagreement as to which method is better. However, these procedures have not been investigated for their application to tempera paints. Some experimental emulsion methods require two short stages of shaking with a few minutes' rest in between. Mechanical agitating devices are mentioned under *Gum Tempera* and on page 321.

The oily ingredients in approved general use are oils, thickened oils, simple-solution varnishes, Venice turpentine, and mixtures of these, such as half stand oil and half damar varnish, three-fourths oil and one-fourth varnish. Laurie[34] says that if a little turpentine is present (as it would be in the case of damar varnish) the emulsification of heavy oils, such as stand oil, is assisted. Together with the majority of writers, he is of the opinion that pure egg-yolk is the best tempera emulsion.

A number of American painters use the following egg/oil emulsion as a standard recipe, varying the composition of the oily ingredient according to individual preferences.

2 parts whole egg
4 parts water

1 part stand oil
1 part damar varnish

When oil and varnish glazes or overpaintings are used with such emulsions it is well to use the same or similar oily ingredients in both, and with any technique which employs alternate complex or multiple layers of paint, careful painters sometimes add an extra drop or so of oil to each succeeding glaze or paint coat in order to produce a correct gradation of flexibility.

Egg/oil emulsions which employ the separated yolk rather than the whole egg are much more likely to exhibit the defects previously enumerated. The following recipe is an example of one of the countless variations which may be made.

3 parts egg-yolk
1½ parts water

1 part stand oil
1 part damar varnish

In the Papers of the Society of Mural Decorators and Painters in Tempera, Vol. II,[39] Hart gives the following recipe for egg-yolk/oil tempera, and accompanies it with very detailed instructions which are briefly outlined below

Yolk of 1 egg
10 drops of oil of lavender
Washed and sun-clarified linseed oil equal
in volume to the yolk of egg
Twice this volume of water

Very careful precautions are taken to keep the white out of the yolk, including rolling the yolk from one hand to the other and wiping each hand after the yolk leaves it. The reason given is that excess albumen would encourage cracking in this formula.

The yolk is emulsified with the oil of lavender by the mayonnaise system, one drop of oil at a time rubbed in thoroughly with the muller on the slab. The egg should become somewhat paler and thicker. It is put in a jar, covered with a damp cloth, and a portion of it returned to the slab where the linseed oil is worked into it in the same way with the muller. After 4 drops have been emulsified, more egg mixture is worked in, and the procedure is repeated, the oil being added in gradually increasing amounts after each addition of egg. When it is finished the emulsion should be a stiff 'mayonnaise'. The two volumes of water are apparently to be added at the end, small portions at a time.

This medium is used in the same way as the other egg/oil temperas, but its author recommends that an additional part of a special varnish be emulsified with it for use with ultramarine, cobalt blue, and the cadmiums. The varnish is one part of hard copal dissolved in tetrachlorethane (a powerful chloroform-like solvent) and then mixed with ½ its (copal?) volume of raw linseed oil. The volatile solvent is allowed to evaporate completely (without boiling) before the varnish is used in the emulsion formula. According to its author, the resulting product is not to be confused with the undesirable cooked copal varnishes.

The careful and meticulous instructions for emulsions given by Hart and other writers may be considered by many practical painters to contain unnecessary over-refinements, but the concern over a complete and thorough emulsification of the oil is not unfounded. In the case of the above formula if care be taken to insure complete dispersion of the oil the results will be superior to those produced by a casual shaking. The small amount of lavender oil assists in the emulsification and the formation of an oil-in-water type of emulsion; it is more or less evaporated during the subsequent mulling.

Studies on the commercial production of emulsions of very similar composition show that the beating in of a very slow and steady stream of oil will in many cases produce a more stable emulsion than can be made by adding successive portions. Mixing the above formula with a high-speed mixer or beater, pouring the oil into the egg in a very slow stream, should give results at least equal to those produced by the mulling method described, but about three times the amounts of the original recipe would be required for the efficient use of such equipment.

Friedlein[40] gives a recipe for egg/oil emulsions: 30 grams separated egg-yolk (about 2 yolks), 20 grams of oil, and after these are thoroughly mixed, 20 grams of water shaken in, in small successive portions. His favourite formula contains ingredients of doubtful value: 150 parts of separated egg-yolk (10 yolks) emulsified with a mortar and pestle with 75 parts of poppy oil, then thinned with 20 parts of water and 10 of glycerin. I have made many experiments with separated egg-yolk emulsified with the usually approved

oily ingredients, but have not succeeded in improving upon the all-around results of straight egg-yolk, gum emulsion, or whole egg/oil tempera.

Experiments with tempera emulsions call for careful, accurate measurements and separations, and a record of the formulas should be preserved in a notebook. Samples should be painted out on glass and also mixed with pigments and painted out on paper or gesso-coated paper, and observed for drying, flexibility, brushing qualities, yellowing, binding, and adherence.

Egg-White Mediums. Egg-white, or glair, has been used to a minor extent in painting techniques from early times, especially in the application of colours to illuminated manuscripts, but its poor brushing properties limit its use for techniques which demand any degree of flexibility or variation in manipulations. It is virtually a pure colloidal solution of albumen, it has comparatively weak film-forming and binding qualities, but it reacts in the same way as the other substances of its class in that it becomes denatured (coagulated) when exposed in thin layers to air and sunlight, and its consistency is altered by agitation or beating. Its dried film is a little more soluble in water than some of the others; like a gelatin or glue film, it may be hardened with formaldehyde. Medieval recipes call for beating it to a frothy liquid; sometimes it was used to bind very pale or very reactive colours which gave less desirable effects when mixed with egg-yolk. Its sole desirable use in modern tempera painting is as a constituent of those egg/oil emulsions in which the whole egg is used instead of the separated egg-yolk, as in the traditional pure egg tempera method. It appears to contribute a stability to such emulsions, probably because the additional colloidal solution of albumen overcomes any tendencies on the part of the other ingredients to form undesirable or unstable types of emulsions. When egg-white is employed on a commercial scale, as it is in various industrial processes, a dried material is used. This is available on the market in a form resembling crushed gum arabic, and is called egg-albumen. Egg-white is used more successfully as a size for attaching gold leaf to gesso, picture frames, and leather than for painting purposes. A popular conception is that, because it is colourless in comparison with the yolk, egg-white was extensively used in early paint mediums; but it was never used to any extent in standard, well-developed easel painting techniques. Its mention in this connection is an example of the type of inaccuracy that finds its way into compilations and accounts written or translated without first-hand knowledge of the subjects.

Gum Tempera

Emulsions made from gum arabic produce satisfactory tempera paints, and when glazed or overpainted with thin oil and varnish mediums they can be used to duplicate some of the luminous qualities seen in the later Flemish and Italian glazed tempera works. Because gum arabic does not alter in process of drying as do egg-yolk, casein, and albumen, but merely deposits a mechanical film by evaporation, its film is not quite so water-resistant as those of the other temperas, and greater care must be taken to avoid the picking up

of the underpainting when a second coat is applied, especially when the underpainting is freshly dried.

Gum solutions, however, will combine with a large number of oils and resins without turning dark and if the brush stroking is carefully done, they may be overpainted in much the same way as the others. Gum arabic has been used as a painters' material from the earliest times; it is generally considered that it was employed along with improved oils and varnishes during the early period of improvement of the tempera technique. The less soluble variety, gum Senegal, should be used whenever it is obtainable.

Gum emulsion mediums are permanent, they are a little easier to manipulate than egg emulsions as they can be made to dry more slowly, and they are capable of producing a great number of effects; either smooth, thin painting or heavy impasto may be produced by them. Their most important advantage is that their formulas may be more widely varied within the bounds of sound practice than those of the other emulsions. They are therefore more adaptable to the requirements of the individual.

Gum arabic is dissolved to a heavy, syrupy consistency, and the oily ingredient is stirred into it slowly. Emulsification takes place immediately; the mixture has a milky appearance; but the rule for making perfect emulsions of this type demands that the mixing or shaking be continued vigorously for some time.

A convenient mixer for preparing emulsions is an inexpensive egg-beater and glass jar to fit, procurable in kitchenware departments. A better piece of equipment which also finds many other uses in the studio workshop, is a small household electric mixer; the kind which can be held in the hand as well as set in its support is most convenient. Three to five minutes' mixing with this produces emulsions which, if properly formulated, will not separate on long standing. (See page 321.)

Typical gum tempera emulsion (parts by volume):

5 gum solution
1 stand oil
1 damar varnish
¾ glycerin

The gum solution is made by pouring 5 fluid ounces of hot water on 2 ounces of crushed or powdered gum arabic (2 ounces of finely pulverized gum arabic will equal approximately 2½ ounces by volume—it will be slightly less). The damar varnish is the usual 5 pound cut mentioned under varnishes.

The oily mixture is added to the gum solution in a slow stream with constant agitation which is continued until the mixture is a thick white liquid, homogeneous, and free from large globules or drops of oil. If no mixer is available, the emulsion may be made by shaking the ingredients together in a tall bottle no more than three-fourths full. The glycerin is to be mixed in thoroughly after emulsification of the gum solution with the oily ingredients. This recipe may be used as a starting point by painters who wish to develop

a medium to suit their particular needs. Variations in the proportions of oily and aqueous ingredients will change its film characteristics. Increase in the amount of glycerin will improve its brushing qualities but will also increase its solubility.

In addition to the advantages previously listed, this type of tempera emulsion uses only permanent, time-tested materials, and has oily ingredients the same as those which go to make up some of the most approved glazes, thus producing glazed pictures of correct physical structure.

Solutions of gum arabic decompose upon standing, but to a much less extent than do those of casein or egg. Gum tempera medium will keep in tightly sealed bottles for over a year; but if the bottles are imperfectly corked so that a little air can get in, it will soon develop mould on the surface. Glycerin has a definite preservative effect and helps somewhat to retard decomposition. Generally speaking, it is not worth while to complicate this easily prepared and long-lasting emulsion by the addition of preservatives, but should the occasion require it, either sodium orthophenyl phenate, described on page 284, or a 10% solution of phenol (carbolic acid) may be used; with the latter, an addition of 1% of the volume of the emulsion is generally sufficient. A small amount of pine oil added to the oily ingredient will act as a mild preservative and will also improve the odour of a gum emulsion. The properties of glycerin and gum arabic are mentioned further under their respective headings. The emulsion itself holds together well on storage; if it does not contain too much water, there will be only a slight creaming, and the emulsion can be made homogeneous again by a little shaking. Gum arabic and oil can also be emulsified by another method; a formula of Friedlein's[40] is as follows: 100 parts of pulverized gum arabic are well ground with a mortar and pestle until free from lumps. Measure 150 parts of poppy oil and 120 parts of water into a wide-mouthed glass, dump this into the gum arabic in the mortar, and rub continuously until emulsification is complete. This will take only a short time. Then add 20 parts of water in small successive portions.

Cherry gum has been used successfully in tempera and may be substituted for gum arabic in the above formulas. Some tempera specialists believe that it is superior to gum arabic. Its use dates from very early times and it may be a more authentic material than gum arabic for duplicating some of the older temperas. It is described further on page 280.

A typical or starting-point formula is the following (proportions given by volume):

12 parts cherry gum solution (2 ounces gum and 6 fluid ounces water)
4 parts stand oil
4 parts damar varnish
1 part glycerin

Wax Emulsions

Tempera paints made with wax emulsions have many good qualities. They are quite resistant to external moisture and their colour effect is bril-

liant; if the paintings are burnished or polished with a soft cloth or absorbent cotton, a lacquer-like effect will be achieved without varnishing. However, unless it is important or highly desirable to retain the original finish, it is perhaps safest to varnish them as one would an oil painting.

In order to employ beeswax in tempera emulsions, it is first necessary to saponify it; that is, make it into a soap by heating it with an alkali solution. If the formula is not accurately compounded and an excess of alkali is present, free alkali will remain in the emulsion and the resulting medium will turn yellow.

The use of saponified beeswax in painting mediums is of great antiquity; references are to be found in the earliest writings and in the records of most later periods, but there are few if any standard, complete techniques established in modern practice. Investigators believe that one of the means the ancient painters had for making a fluid paint before the days of turpentine and other volatile solvents was the use of a waxy medium that could be thinned with water. At present its use is confined to painters who adapt it as a result of independent experiment.

Wax soap is best prepared by boiling 1 ounce of white beeswax with 5 fluid ounces of water and after it has melted, pouring in slowly with stirring, ½ ounce or a little less of ammonium carbonate which has been mixed to a creamy consistency with a little water. A teaspoonful of half-strength ammonia water may be substituted for the ammonium carbonate if desired. Continue the heating until all the ammonia gas is driven off and allow the mixture to cool, stirring occasionally. This wax soap will be pasty and usually must be warmed before use; if a creamier consistency is required, increase the original amount of water. Emulsification with oily ingredients is assisted if an ounce or so of turpentine is added before putting in the alkali. If the wax soap is emulsified with egg or some other aqueous medium, the resulting mixture may be freely thinned with water.

Among the materials most recommended as ingredients of wax emulsions are simple-solution varnishes, oleoresins, casein, glue, and gum solutions; as plasticizers, glycerin and castor oil. The drying oils are generally condemned on account of their tendency to cause such emulsions to turn yellow, but stand oil and some of the modern varnish linseed oils may possibly be suitable. Further uses of beeswax are noted under *Waxes*.

Wax soap must be entirely free from uncombined alkali if it is to be mixed with resins or oils; otherwise soaps of these latter materials will be formed. Careful users will warm the wax solution until all ammonia odour has disappeared or until the mixture no longer turns red litmus test-papers blue.

Tempera mediums which contain wax are not easily managed or controlled and must be accurately made and well tested to guard against erratic behaviour. In the hands of an experienced painter they are capable of being applied to work of great delicacy. Very few of the published wax tempera recipes can be used directly without some experimental adjustment.

Friedlein[40] gives the following recipe for a wax preparation to be used in

emulsions: melt equal parts of white wax in castor oil; remove from the stove and thin with five parts of turpentine; keep in a tightly closed can, and use by emulsifying with egg, casein, gum, etc. Typical formulas for such emulsions are: 15 parts of wax mixture to 10 parts of gum solution; 100 parts casein solution, 60 parts wax mixture,and 50 parts water. This wax preparation, unlike the saponified wax, is purely an oily ingredient and is meant to be emulsified with hot aqueous solutions.

Oil Tempera

Under *Emulsions*, on page 307, mention is made of a water-in-oil or reverse type of emulsion in which the water is dispersed in minute globules in the oil. Such emulsions may be thinned only with turpentine or other oil-miscible solvent and not with water, and so if it is desired to add a little more water to such mixtures than that which naturally comprises half of the yolk, it must be mixed with the egg before the emulsification.

Egg-yolk carefully separated from the white and mixed in the proper way with no less than twice its volume of stand oil will result in a medium that has very interesting properties. Laurie[34] suggests that it may have been used in the fifteenth-century Flemish method. (The usual reconstruction of this method employs painting wet into wet with aqueous tempera and oil-resin mediums.) The definition of tempera given at the beginning of this chapter does not cover this type of emulsion; yet from the point of view of its use, behaviour, and effect, it is classed among the tempera mediums.

A few drops of egg-yolk or egg-yolk and water mulled into a tablespoon of stand oil, other oil, or a mixture of damar and oil in the manner described on page 173 but with the omission of the oil of spike or other volatile solvent, will produce a medium which can be diluted with turpentine instead of water and which has working properties different from those of any of its ingredients and from those of aqueous tempera. Its film will not usually dry faster than its oily ingredients alone, nor will it be more resistant to the action of solvents. The properties of the medium will change as more drops of egg are added and when the volume of egg or egg solution passes one-third of the total, the mixture will change to the oil-in-water type, which is miscible with water. The presence of much turpentine in the oily ingredients seems to favour the formation of the oil-in-water type.

These emulsions have often been employed by experimental painters, but because no standard tradition has been established they must be closely observed and tested before being used, to make certain that they are homogeneous mixtures miscible with solvent and that they will dry well. The presence of finely divided pigments is helpful in the formation of water-in-oil emulsions; tube oil colours can be used in their preparation.

There is an impression among some that if the ingredients are properly balanced, an emulsion can be made which may be diluted with either water or turpentine. This is not in accordance with the present theory of emulsions, and such a condition would be of doubtful value in any case.

Balance of properties for all-around use is more difficult to achieve in water/oil emulsions than in oil/water emulsions; the film usually has many of the characteristics of the oily ingredient, especially its solubility. One part of egg-yolk emulsified with one to two parts of heavy damar (8 lb. cut) and thinned with one part of turpentine gives a non-yellowing painting medium which handles well but which is as soluble in turpentine as is straight damar varnish. This emulsion keeps for a long time in bottles.

The statement that each of the two types of emulsion may be thinned only with its appropriate solvent applies to ordinary brush dilution or thinning. Mulling or shaking with additional liquids will usually cause further emulsification and may result in a change of type, depending on conditions.

Casein Tempera

Emulsions of casein solutions with oils are easily made. They have good structural or film-forming qualities and are quite stable, but they invariably have the unfortunate property of turning yellow or brownish-yellow with great rapidity. Casein-oil tempera should never be used for permanent work, and oil should never be used in casein grounds if their brilliance or whiteness is to be preserved. Although prepared tempera colours made with casein have been sold in tubes there have been no standard methods or formulas in common use, and the artist who wishes to employ casein emulsions must do his own testing. Non-yellowing emulsions of casein may be made with saponified wax, Venice turpentine, damar varnish, etc.; any tendency of the medium to turn yellow will soon be disclosed if it is ground with zinc white, painted out, and exposed to sunlight in the same manner in which pigments and varnishes are tested (see page 96). Simple casein solutions for use as painting mediums cannot strictly be classed as temperas, because they are not emulsions. See page 278.

Techniques of Tempera Painting

The oil painting process came into use and largely supplanted tempera, as an entirely different technique which could produce entirely different effects; water-colour painting is used for the same reason; and tempera owes its present popularity mostly to the fact that it produces paintings of a character different from that of oil or water-colour work. There is, therefore, little reason to attempt the imitation of oil or water-colour effects in tempera; if these are desired, one had better use the appropriate medium.

Long experience has acquainted us with the advantages of each medium, we have become accustomed to certain ideas of how each one should look, and we are usually prone to be rather critical when the effects of a medium do not comply with our notions of what is fitting. Before beginning his work the artist has a visualization of the final results, and decides the details of his technique on the basis of his preferences and experience.

The traditional tempera techniques are all based on deliberate, methodi-

cal, well-planned procedure—particularly those which employ oil or oil-resin glazes, where, as has been mentioned previously, the optical effect depends upon built-up elements or layers rather than upon the constitutive properties of a single direct medium, as in oil painting. However, within limitations tempera is also applicable to more spontaneous or direct methods of painting, and it is beyond the province of any commentator or instructor to determine the limits on technical grounds, although he may justifiably criticize the results of an inappropriate application of materials. Some painters are personally or temperamentally able to use the tempera medium successfully in a much more direct manner than others; the majority of those who favour tempera, however, prefer the methodical step-by-step construction.

The usual or standard procedure, based on the traditional pure egg-yolk technique, is to make a complete drawing and trace it upon a gesso panel which has been brought to a smooth, fine, ivory-like finish. The artist has a clear idea of the final effect which he desires in his picture, and, depending upon his preferences, may either trace his drawing in detail or merely outline the significant or guiding points. If the drawing is made directly on the gesso with a lead pencil, care must be taken not to clog the white surface with too many soft smudgy pencil marks or mar it with the scratches of too hard a pencil. Pencil lines or tracings are strengthened by going over them with a pointed water-colour brush, using diluted water-colour or ink of any shade; however, if the tempera painting is to be thin and rather translucent, these lines should not be so strong in colour as to show through and produce an aquarelle or unsubstantial effect, which is generally not in keeping with the more opaque tempera effects. The painting is done thinly with much dilution of the colour, achieved by dipping the brush in water, and colour gradations are made with fine strokes or hatches rather than by the oil technique of blending or scumbling. Red sable brushes are used more often than bristle brushes, but this is again a personal matter. Most experienced painters prefer that the brilliant white ground be covered up immediately, with at least a thin veil; its luminous effect will always be there, but its actual appearance should be guarded against.

If the painting is not to be glazed, full, deep-toned colours are used from the first in its execution; if it is to receive glazes, the undercoat is ordinarily kept very pale or chalky, resembling the tones popularly called pastel shades. The actual hues and shades used in underpaintings are a matter of preference based on experience; usually the final colour reduced with white will suffice, but for some effects there is an advantage in using a cooler or a warmer shade of the same hue, or an entirely different colour. The brilliant red draperies of some old paintings were often made by applying a glaze of some lake such as madder over a rather strong tint of vermilion. Blue skies were underpainted with a pale yellow or pink; flesh tones with a variety of transparent colours. Sometimes the flesh was completely modelled in cool monotone, and then given a warm, lifelike, transparent glaze; sometimes green earth and white were used in such underpainting and sometimes a full range of very pale

colours. One method of painting the earth in a landscape was to model it completely with burnt sienna and white, overpainting local hues with both opaque and transparent colours. All of these procedures and modifications of them are in use. If the technique and methods of a painter have been established through oil painting or water colour he will find that obvious adjustments of his methods must be made but that control of the medium will usually come after a little practice.

Wet-into-Wet or Mixed Techniques

When colours which have been ground in an oily glaze medium are glazed or not too heavily painted over a tempera underpainting or directly upon a sized gesso panel, and the work is continued by painting with aqueous tempera into this oily layer while it is still wet, a sort of crisp contrast in textural and optical values is achieved. The effects are sufficiently different from those of other methods to be placed by some painters in a definite class by themselves.

Many of the effects produced by variations and extensions of this method cannot be duplicated satisfactorily by other means, and investigators have long attributed to this procedure certain results obtained by the early schools of painting, especially by the fifteenth- and early sixteenth-century Flemish and German painters; the method is also thought to have been used during the transition period prior to the adoption of straight oil and oil-resin techniques; statements in early writings substantiate both of these contentions.

Two entirely different effects produced by wet-into-wet painting are the depiction of very fine crisp lines (such as hair in portraits), generally done with the point of a small brush, and in the loose, free, rather draggy opaque areas of pale colour or white surrounded by or covered with transparent glazes of deeper, darker tones. In the latter case various effects are produced by playing the opaque tempera and the transparent or translucent glazes against one another and by confining the cool or the warm side of the palette to one or the other.

The principle is subject to considerable variation on the part of individual painters, and if they find it suitable to their requirements they are most likely to use it in a personal or individual manner. It may be employed throughout a picture or for occasional effects. As remarked in the section on water-colour painting, any picture which combines opaque and transparent effects must be either well planned in advance or executed by an experienced hand in order to avoid unpleasant optical results.

If painting into wet layers is confined to separate brush strokes rather than covering broad flat areas, if there is a close connection between the ingredients of the oily and aqueous mediums, and if the layers of oily medium are kept very thin, cracking does not occur. Use of tempera and oily mediums of too widely divergent properties and use of extensive areas of tempera over thick oily layers should be avoided.

Thick or impasto tempera should be used only in the first layers; if the

picture requires going over by repeating the alternate coats, then the additional tempera as well as the oily paint should be kept very thin.

The most popular and successful materials in use for this sort of painting today are (1) a whole egg/oil emulsion used in conjunction with a glaze medium made from ingredients which are the same or have the same properties as those of the oil or resin content of the emulsion; (2) a gum solution/stand oil-damar emulsion used with the stand oil-damar glaze medium. Final glazing coats, especially if they are to cover the entire picture or to be used on considerable continuous areas, should contain a little extra oil in order to assure the proper structural flexibility, and if drier must be used anywhere in the picture it should be kept to an absolute minimum. The addition of cooked varnishes such as copal and other commercial types is likely to cause rapid checking of glazes in an 'alligator' pattern. In some techniques, particularly with the gum-tempera procedure outlined above, and for final glaze coats, regular tube oil colours drained by spreading them out on paper for a while, may be mixed with the oily or resinous medium to a glaze consistency instead of grinding dry pigments directly into it. As a general rule, if paintings executed in the mixed technique are going to fail by cracking, this defect will display itself immediately after they become completely dry, or within a very few weeks thereafter; if no such early failures occur, work of this type may be considered to be as durable as any other form of tempera painting.

Ready-Made Tempera Materials

Most of the materials necessary for painting in tempera may be had ready-made, but, in order to secure perfect control of the technique so that it may be adapted to their individual requirements, and also for reasons of economy, many painters prefer to make their own. Although excellent results as to both durability and satisfactory application may be secured by the use of prepared materials, it is generally conceded that some first-hand experience and knowledge of their composition and preparation is necessary for their proper use and selection. Such experience enables a painter to identify the general nature of the prepared materials and, if necessary, to adjust them to his requirements.

Poster or show-card colours sold in jars are sometimes labelled tempera and so called by commercial artists; this practice seems to be increasing. Correctly, these colours, which are mostly of the simple gum-water, glue size, or distemper type, should be known as poster colours. The adoption of the term tempera by some makers in this country seems to have been prompted by the need for a name to distinguish the finer grades of poster colours from the inferior kinds. True tempera paints are never sold in jars, but in tubes; their use is highly developed in Germany, where all sorts and varieties are made—good, bad, and indifferent. I am well acquainted with only one American brand of prepared tempera colours* (Martini); these are

* Prepared tempera colours are normally supplied by several British firms, notably Messrs. Rowney and Messrs. Roberson; owing to the rationing of eggs they are at present not manufactured.

said to be carefully made from an egg emulsion and they have been used with success by many painters; others prefer the working qualities and effects of their own particular mixtures.

The valuation of prepared tempera paints is, in general, quite simple, at least for the artist who has made his own and is familiar with their requirements; the principal test is whether they will perform in the desired manner when subjected to his manipulations. The yellowing of improperly combined mixtures, such as casein with linseed oil, and the fading of impermanent colours show up after a month or two of testing by exposure to sunlight in the usual manner.

Laurie[34] suggests that prepared tempera paints be tested for alkalinity with litmus paper, and that a lump of the colour as well as a brushed film be placed on glass and allowed to dry for a month. At the end of this time it should not have cracked, and if left to stew in hot (not boiling) water for several hours it should neither disintegrate nor separate from the glass. As mentioned in connection with prepared painting materials in general, the reliability of the maker is also an important consideration.

Gesso panels on plywood and cradled Wallboard will be made to order by some artists' suppliers; the process and its principles are simple enough to lend themselves to commercial production without any difficulties, and there is little reason for the substitution of inferior materials. The artist may quite easily judge for himself by an examination of their workmanship and surface properties whether or not they are of high quality.

Prepared tempera emulsions of secret composition are best shunned, unless they are sold as being the same medium as that employed by the firm in question to make prepared tube colours which the artist has selected as suitable for use. Other liquids for tempera painting, such as glazing mediums, varnishes, etc., present the same problems as do similar products for oil painting; very few of them are sold with a complete, unequivocal analysis of their exact percentage composition.

5

Grounds for Oil and Tempera

The material upon which an oil or tempera painting is executed is divided into two parts; namely, the actual surface or ground, and the support which is the foundation, backing, or carrier for this surface.

The three chief grounds in general use are oil grounds, gesso grounds, and emulsion grounds which are a mixture of the first two. A number of other grounds enjoy less popular use.

The principal supports in use are wooden or composition-board panels, textile fabrics stretched on wooden frames, and, rarely, thin sheets of metal.

Canvas

The word canvas does not refer to any specific material in the field of textile fabrics, but is applied to a number of closely woven materials of relatively coarse fibre, such as are used for sails, tents, awnings, etc. In painting, the term canvas generally implies a coated fabric, ready for use; the word is also employed by commentators to mean a finished oil painting.

Practically every closely woven textile has been utilized at some time as a support for paintings. Legend tells us that linen canvas stretched on wooden frames was first used for paintings of religious subjects to be carried through the streets in processions, especially in Italy. However, cloth as a support for painting was known to the ancients, and it was a logical material to turn to when artistic oil painting was introduced. Cotton canvases, such as duck, sailcloth, and twill, came into occasional use after the commercial production of cotton, but they are entirely inferior to linen; they stretch poorly, they tend to give an inferior surface, and most of them do not take the size or priming well. Only the cheaper sort of ready-made artists' canvas is cotton. The best material is a closely woven pure linen with the threads of warp and woof equal in weight and strength. Linen-cotton mixtures are probably worse than pure cotton; their uneven absorption and discharge of atmospheric moisture will cause variations in tension. Jute becomes very brittle and lifeless on short ageing and should not be used.

Commercial canvas has an advantage in that it is coated by machinery or in a shop well equipped to provide a mechanically even hand coating by expert workers, who can force the coating well into the weave with a minimum use of materials; but the home manufacture of canvas has a greater advantage in that it makes possible the selection of materials solely on the basis

of the artists' criteria of permanence, suitability, etc., unhampered by certain considerations which must be taken into account in commercial manufacture, storage, and distribution.

During the early nineteenth century a smooth canvas with a diagonal or twill weave was in wide favour, especially for portraits. Prior to the introduction of improved mechanical weaves, a hand-loomed square weave of coarse single strands was used; this was often a very open weave and required a filling of thick glue.

Priming Oil Canvas. Stretch the linen, driving the tacks only part way into the stretcher, and moisten the canvas evenly with water. When it is dry, tighten and restretch permanently. Impregnate the canvas thoroughly with size. Oil paint should never come in direct contact with the fibre, or the canvas will rot. This has been known to artists for hundreds of years, and the earliest examples of oil paint on canvas are found to be thoroughly sized with aqueous glue. When the size is dry, apply the priming with a brush in even coats, as thinly as possible. Work the paint well into the cloth; use a scraper to remove excess of first coat if necessary, the idea being to apply as thin a coat as possible. The scraper is a tool with its edge at the end, similar to a very wide putty knife; it is commonly called a wall-scraper (see page 94). For general use it should be of fine quality, about 3 or 4 inches wide; the most limber, flexible one should be selected from the dealer's supply. The cheaper, inflexible kind is less useful.

White lead in oil produces a satisfactory coating; white lead and zinc (in proportions of from 40 to 60% of either) produce a better one. This may be thinned with a mixture of turpentine or mineral spirit and, if necessary, a little refined but not specially bleached linseed oil. Just enough liquid (linseed oil-turpentine mixture) is to be added to make brushing possible, and it should contain only enough turpentine to produce the desired semi-mat, slightly absorbent finish. Too much turpentine will result in absorbency, porosity, and lack of toughness and durability. The film produced by zinc white alone is too brittle. Titanium pigments also have defects, and should be used for grounds in not more than 40% proportion with white lead or zinc. Lithopone (not recommended as a pigment for painting) is satisfactory for grounds when used alone. When additional tooth or coarseness is desired, a coarse, inert reinforcing pigment, such as silica or pumice, may be ground into the paint up to 10%. No dry pigments should be merely mixed with oil for priming purposes; they must be ground—not necessarily finely ground but mulled enough to insure wetting of the individual particles and uniformity of the paint film. Canvas for oil painting is commonly prepared by the application of two coats, the second being applied thinly and carefully as soon as the first is dry enough. When coats of different composition are used, it is always better to apply the coarser one first and always absolutely necessary to apply the more flexible one last. Most commercial primings are tinted slightly grayish to overcome a tendency toward yellowing.

Aqueous grounds also require a preliminary sizing of the fabric if they are to be applied successfully. The usual preferred sizing material is hide glue,

dissolved according to the procedure described under preparation of gesso on page 200, but diluted with water so that it forms the weakest sort of semi-jelly on cooling. Casein and other animal glues of good quality may also be used, but they too should never be made up in strong or adhesive concentrations. Casein has been widely recommended for this purpose, because when dry it is much more water-resistant than glue or gelatin; but glue appears to be in wider use because it is more flexible. The moisture resistance in both cases is greatly increased by the use of formaldehyde, as explained elsewhere in this section. After the glue or casein size has dried, both sides of the canvas may be sprayed or brushed with the 4% formaldehyde solution.

A size is not a cement; it is a penetrating liquid employed to fill pores, to isolate coatings, or to make surfaces suitable to receive coatings; it is not intended to form a continuous, level film. This is an important distinction, and one not always realized. It is difficult to give any strictly measured or weighed formulas, due to the variation in glues, but about 1½ ounces of rabbit-skin glue to a quart of water will not be far from the correct amount.

Direct application of oil to linen, definite and inevitable as its rotting effect may be, is no more ruinous to an oil painting (and is usually more amenable to conservation treatments) than a heavy film-forming coat of glue or casein, such as is sometimes found underlying an oil ground, particularly in eighteenth-century paintings. Glue, unreinforced by pigment as in gesso, or by starch or dextrin as in relining and industrial techniques, has little stability as a continuous film of appreciable thickness, especially under several coats of oil paint. The movement caused by its continual absorption and discharge of atmospheric moisture often results in a complete and heavy scaling of the entire picture, a condition that can be repaired only by transferring the paint film and removing the size, one of the most exacting and laborious of restoring techniques.

As remarked elsewhere, linseed oil is not a good adhesive, and the film of an oil ground should be allowed to get some sort of hold in the interstices of the canvas, which should be isolated from chemical action but not from a mechanical bond with the oil ground. The anatomy of an oil painting and similar matters discussed under *Conservation* may be referred to in this connection.

The ground is not merely a first coat of paint over the support; for permanent wearing qualities it should not be dispensed with by painting the picture directly on the support. Besides supplying the necessary white colour, uniform texture, degree of absorbency, etc., it furnishes an intermediate structural layer between the support and the painting layers.

The sizing of canvas with a solution of cellulose has been suggested on the theory that it will not rot the cloth, will not absorb and discharge atmospheric moisture, and will be chemically the same substance as the fibres. To this suggestion I would add the precaution that care should be taken to use this material sufficiently dilute to be a size which merely seals the absorbency of the fibres, and not an actual film; cellulosic coatings will form continuous films even when quite dilute, and such films would present a rather pre-

carious bond for the oil paint. Any one of the pure solutions of cellulose or pyroxylin lacquers may be used together with any convenient solvent, and because of the present novelty of the procedure and its experimental nature, it would be well to make a permanent notation of the combination on the back of the canvas. These materials produce films which are totally foreign in composition and properties to the usual painting materials; this feature may be of greater significance than the fact that they are related in composition to the textile fibres. Glue size leaves little to be desired from a functional viewpoint; its incomplete resistance to moisture, or its hygroscopicity, is its only fault, and this can be overcome to a large extent by tanning the back of the canvas with formaldehyde (see page 323).

Circumstances sometimes make it necessary to roll finished pictures, but they should preferably never be rolled. When it is unavoidable, they should be rolled around a cylinder of as large a diameter as is convenient. Canvases should always be rolled face out; the tension produced is less injurious than the compression caused by rolling them with the painted side inward; also when they are unrolled, the strains of tension are relieved and the danger of cracking diminished rather than intensified, as would be the case had they been rolled face in. The practice of placing paper over the painted surface is generally not a good one; it is likely to cause more damage by adhering tenaciously than the canvas causes by rubbing. Gesso or semi-gesso grounds on canvas will usually begin to crack immediately when rolled.

A much better way to preserve unstretched pictures, especially old ones, is to thumb-tack them face down to sheets of wallboard, so they lie flat. For shipping purposes they may then be covered with another piece of wallboard and tied securely with twine.

Well-made modern linen canvases should give permanent service; the best firms have apparently profited by the experience of past generations of canvas makers, with the possible exception of their tendency to use linen that is too thin or light-weight. The disintegration of old canvases around the edges of the stretcher frame is common. Early nineteenth-century English and American pictures on commercially prepared linen canvas are often found intact after more than a hundred years of storage under average circumstances, but a considerable proportion require relining or reinforcement at the edges from seventy-five to one hundred years after being painted, even though the face of the picture is intact, particularly when the canvas was primed after the stretching and the folds and margins were not sized and protected by the priming. Few eighteenth-century oil paintings of value in collections have survived intact without being treated by restorers.

The cloth is obviously the weakest point in the survival of a well-made picture; but previously mentioned advantages, including the important fact that defective paintings on canvas can be repaired or conserved more satisfactorily than those on other supports, have caused linen to retain its position as first choice as a support material ever since it came into general use. Of the painters who use oil grounds on panels, the majority do so because they prefer

the smooth, textureless surface rather than for any advantages resulting from the rigidity.

Stretchers. The universally used stretcher bars of the tongue-and-groove type, with mitred corners and bevelled sides, are made by automatic machinery and are superior to the older kinds. They are generally made of selected pine or ash, kiln-dried. The ordinary dimensions of those carried in stock in artists' supply stores are: 1½ inches wide, about ⅞ inch thick, and from 6 to 60 inches long. Special lengths in fractions of an inch, as well as stretchers with the greatly desirable crossbars, can also be obtained on order.

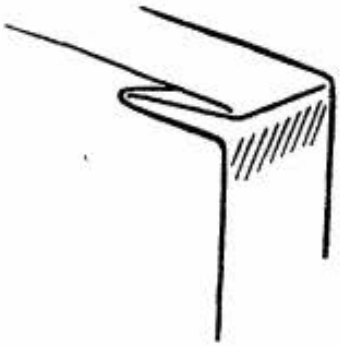
Much more rigid and durable stretchers are those 2½ inches wide, bevelled on one side only; they are not kept in stock but are made to order. These heavy stretchers should be used on large pictures and in the conservation of old or relined paintings of any size. If crossbars are ordered on these stretchers they will usually be keyable; those on the common-weight stock will not be, unless so specified. Stretchers are always made about ¼ inch short to allow for keying; if exact length is required of made-to-order strips, that fact should be specified. This is sometimes important when the painting must fit an old frame or when canvases are to be restretched.

In France the dimensions of canvases and frames are standardized into 57 numbered sizes, 19 each of three shapes called *figure*, *paysage*, and *marine*. This system is advantageous in that a large selection of both canvases and frames in conventionally pleasing shapes constitute stock items which can be ordered by number. A common notion is that the system has been arranged according to some mathematical law of proportion or symmetry, but more probably it was arranged by dealers and artists to afford the greatest possible number of choices with a minimum of stock.

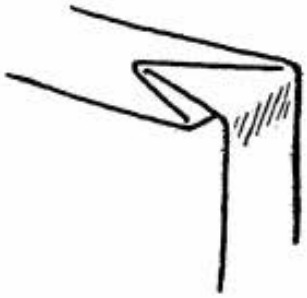
Stretching Canvas. The usual method of stretching ready-made canvas is to line up the weave carefully parallel to the sides of the stretcher and tack the canvas at four places, once in the middle of each side, drawing it fairly tight. The first tacks will require removal and replacing after the canvas has begun to be stretched to its full tautness; therefore they do not have to be driven in very deep. The use of drawing-pins for preliminary stretching or for canvases which are certain to be removed from the stretcher soon, sounds reasonable, but even when of the largest size they have an annoying habit of popping out under the tension of the stretched canvas. Most painters use very small tacks, but their heads do not grip the canvas well after age has affected the picture; No. 6 is a good size for general use, but the size must be varied according to circumstances. At the corners, where three thicknesses of canvas have to be held, sometimes tacks as large as No. 14 may be employed. The surfaces of the heads of ordinary carpet tacks will usually rust with age. This is not a matter of importance, but it has prompted some painters to use copper tacks. These are not so good; they do not hold well and they are so flexible that it is difficult to drive them correctly. Copper nails less than ¾ to 1 inch long are not usually satisfactory for general purposes.

After the first four tacks, eight more are driven in, one on either side of each of the original ones. The canvas should be pulled as tight as possible

with the fingers, regardless of any wrinkling in front of the first four tacks. All the tacks should be spaced evenly, the distance between them depending on the size and nature of the canvas and the experience of the painter. Stretching is then continued in the same manner except that the stretching pliers are used and the next tacks are driven in completely. After a few more tacks have been driven in on each side, each of the first twelve may be drawn and permanently replaced with the aid of the stretching pliers. Stretch each side as far as the point where the tongue-and-groove begins, then finally stretch the corners, being careful to place the tacks on the right-hand ends at the lower edges and on the left-hand ends at the upper edges (right and left when facing the rear of the canvas). The corners are finished by folding the canvas over the right-hand ends. This way:



is neater and trimmer than this way:



The aim should be to stretch the canvas sufficiently so that keys or wedges are not needed to produce the final smoothness, but they should be kept in reserve to tighten the painting should any subsequent slackening occur. When used, they should be driven in uniformly by counting the number of hammer blows. Stretchers which have crossbars should have one key, not two, at each end of a crossbar, and each key should be driven into the side of the crossbar opposite from that into which the key at the other end is driven. If desired, the keys may be held in place by nailing small brads into the inner edges of the stretcher strips, parallel to and alongside of the end of each key. If a small hole is drilled through the corner of a key it may be tied with a loop of twine or wire to a tack or screw-eye driven into the stretcher, and thus be guarded from becoming lost should it fall out of its slot.

Instead of trimming the canvas off at the back edge of the stretcher, some painters prefer, and under some circumstances it is required, to leave a surplus inch or more all around so that the picture can be restretched. I find that a convenient way of retaining this surplus is to paste it down neatly on the back of the stretcher with rubber cement; this allows of its being picked up easily with the fingers when necessary. Corners of the surplus linen may be trimmed away, and after the canvas is cemented down, its edges may be trimmed further by ruling with a razor blade. Rubber cement is not an approved material for use in connection with permanent techniques, especially on paper and with other delicate materials, but it is useful in such procedures as this.

Protection of Canvases from the Rear. Eastlake[14] notes the extremely sound and careful set of precautions in the interest of durability established by the craftsmen of early days and mentions the fact that protection of the back of the canvas or panel was the single safeguard completely overlooked by them. He does not consider the possibility of their having had a definitely adverse opinion of this procedure. The most obvious method, application of a coat of paint or varnish, is not a good one for several reasons.

Nineteenth-century canvases carefully painted on the back have been found in bad condition; this, however, is by no means certain proof that the procedure has no value; we seldom know how or when the paint was applied or just what its composition was. An important objection is that unless the film applied is of almost mechanically uniform thickness, the variations in brush strokes will soon impart their effect to the surface of the picture in the form of lumps and depressions because of unequal tension on the threads of the linen. Another objection has been the interference of such coatings with future repairs to a damaged picture.

Among some of the recommended methods for protecting the back of a canvas are giving it a brush coat of red lead or white lead in oil, coating the linen with tin foil attached with gold-size, impregnating the back with a solution of tannin or formaldehyde to make the size more resistant to moisture, and stretching the canvas double.

An examination of large numbers of American paintings on canvases commercially prepared from 1830 to 1870, and bearing the stencilled trademarks of makers in various American and European cities, shows that, instead of the practice of selling prepared canvas in rolls, canvases were quite often coated after stretching, leaving the margin which is tacked to the stretcher frame uncoated. Almost all such canvases, even when the face of the picture is in excellent condition, become rotted around the edges, often to such an extent that the cloth may be rubbed to a powder between the fingers, and the intact face of the picture is sometimes found entirely separated from the uncoated margin. When linen which is mounted on its final stretcher is being prepared, the sides and corners should be well impregnated with size and coated with paint.

When a sheet of cardboard is tacked to the back of the stretcher or picture frame so that some circulation of air is possible but the canvas is well insulated, the protection is great. Changes of temperature and humidity will affect the canvas more slowly and to a lesser extent than they would without this device, and the covering can always be removed for periodic dusting. An air-tight seal would be less beneficial because canvases protected in this manner seem to rot and become brittle even more rapidly than exposed canvases.

Examination of decayed canvases of great age, of early American canvases, and also of those of 1890–1910, which may be considered equivalent to those in current use, shows almost invariably that the portions of a canvas over the stretcher bars and crosspieces are in a better state of preservation than the rest of the picture; in the majority of cases, unless disintegration was due

to abnormal circumstances, the preservation of these areas is perfect. This has been observed by Ostwald[29] and others, and it shows the efficacy of an independent layer of material at the back of the canvas, even when the protection is only partial.

According to Sully,[16] a beeswax preparation was used to protect the backs of some early American canvases, but pictures so treated do not appear to have survived in any better condition than untreated canvases of the same period. Stretching the linen double is a procedure of some antiquity, but canvases stretched in this manner disintegrate as badly as any others. Possibly the principal advantage of applying paint or other coating to the back of a canvas is the additional rigidity imparted to the picture; when a gesso ground is coated on the back of a piece of prepared oil canvas the gesso resists cracking to a greater extent than when applied to plain linen.

To sum up the methods of protecting canvases from the rear, in the order of their relative value:

1. Spray or brush the back with a 4% solution of formaldehyde (see page 323) after the size has been applied and preferably before the priming coat is laid on.

2. Attach a sheet of cardboard, wallboard, coated fabric, or heavy paper to the back of the framed picture in such a manner that the canvas is not hermetically sealed against all access of air but is well protected against accumulation of dust and dirt, direct draughts of air, and accidental pressure.

3. Leave the picture entirely untreated.

Of lesser or doubtful value:

4. Stretch a double canvas.
5. Seal the rear tightly so that all air is excluded as far as possible.
6. Coat the linen with wax or wax-resin mixture, metal leaf, or tin foil.
7. Coat with oil paint, varnish, or lacquer.

As to the selection of prepared canvas, Laurie[34] recommends that it be tested by working it vigorously between the hands to see whether the priming is firmly attached; also that the yellowing of any particular brand be tested by cutting a sample in two pieces and allowing them to age for three months, one in the daylight and one in the dark; the brand that yellows least should be chosen. Insufficient attention to the quality and condition of prepared canvas is a common failing among painters, and inferior grades or pieces upon which cracking or flaking of the ground has already occurred are often used, when a careful examination before accepting them would reveal their shortcomings and thus preclude rapid and early failures.

Laurie also recommends that all canvas should be kept six months before use, in order to insure thorough drying of the oil; presumably this means first stretching the canvas, then allowing it to age on the stretcher. Old, thoroughly dry canvas will sometimes crack when stretched, especially the end of a roll where it has been tightly compressed. Any ground on cloth can

be made to crack when folded, or bent sharply, but the comparative strength of coatings and their degree of adhesion can be estimated by a vigorous folding.

Wooden Panels

The wood selected by the early Italians for their panels was mostly poplar; that used by the Northern painters was oak. Eighteenth- and nineteenth-century Northern panels are usually mahogany. The Italian panels were generally very thick, the others much thinner. In England well-aged boards from old panelling or furniture were often used. Modern painters often seek such well-aged panels, and when they can be obtained, prefer them to new boards or plywood of recent manufacture. It is general knowledge among investigators and experienced craftsmen that well-made, properly designed panels composed of several plies of wood cemented or glued together are much more resistant to warping and splitting than are solid, one-piece panels. All fine furniture or cabinet work is veneer or plywood.

The best ready-made ordinary plywood universally available from the plywood dealers is five-ply birch, $\frac{13}{16}$ inch thick; it is constructed with a thick lumber core (usually poplar or gumwood) to each face of which two thin plies of birch have been glued, with their grain running in opposite directions. Such panels are also made with maple, walnut, mahogany, and other facings, and in a number of fancy grainings, none of which have any particular relation to the purpose; but the face should be free from such blemishes as are undesirable. The outer ply should be, so far as the size permits, of one piece; the purpose for which it is to be employed should be mentioned to the dealer; otherwise, a piece with a joint that would make a very beautiful grain effect in furniture work, might be considered by him to be better than a plain panel whose face is one single sheet of wood. The special five-ply maple mentioned on page 334 is preferrred by some painters.

Plywood is customarily sold as 'good one side' or 'good two sides', the latter being more expensive, and unnecessary for our purposes. The 'good' refers to unblemished surface effect. It is not recommended that any of this material be cut with a hand saw, as the outer plies are liable to be loosened and broken away at the edges; a circular saw is better, because the teeth go in one direction only; a band saw is still better. Finer plywoods of similar weight and thickness can be secured at greater expense from specialists who make them to order according to their judgment as to the best kind of wood and the most desirable thickness for each ply. This general type of panel, although heavy and cumbersome, is much more durable and satisfactory than the thinner three- and five-ply panels (approximately $\frac{1}{4}$ inch thick) which are often used for paintings.

The lumber core of correctly made plywood is composed of strips a few inches wide, sawn from planks and assorted so that they do not present a uniform, continuously grained structure; if the core were one plank or pieces assembled from the same plank, there would be more likelihood of concerted

warping and splitting. For the last fifty years or so the outer plies or veneers have for the most part been made by soaking and steaming the logs and then putting them through a machine which peels the thin veneer from them with a knife blade in a rotary manner. Some veneers are made by slicing through a halved or quartered longitudinal section of the log. The usual furniture veneer is made $\frac{1}{28}$ inch thick, but for technical purposes thicker plies are often made. Although the sliced and peeled veneers are dried and delivered in a flat condition, they tend to revert toward a curved shape when made wet again. For this reason, some careful panel makers insist upon using plywood in which all the plies have been made of sawn wood only. The fine, expensive furniture veneers, especially those with rare grainings, are commonly cut or sliced because sawing will waste too much wood; more sawdust than veneer is produced. Panels for painting, however, do not require any rare or finely grained effects, and plywood made with sawn wood of commonplace grain is often obtainable at a fraction of the cost of such furniture panels.

In the majority of instances Presdwood is superior to wooden panels, and I believe that under the average modern conditions it offers the best panel support available, at least for pictures of ordinary easel-painting size. Its properties are described more completely and compared with those of other wallboards in the following pages. Woods vary widely in their properties, but all of them are highly complex structures of cellular and laminated arrangement, subject to a number of defects and stresses which are absent from the denser varieties of wallboard.

WALLBOARD

Wallboard of one kind or another has been in use for light construction work for about a hundred years. The types available on the market can be grouped into several classes. They are all sold at lumber yards.

1. *Laminated boards,* made mostly from paper waste and wood pulp. These are really heavy cardboard, and when cut or broken they may be seen to be constructed of papery material in layers. There are many trademarked brands on the market—Beaver Board, Upson Board, etc.—all of approximately equal value. This material grows brittle very rapidly, and is altogether too fragile for use in any sort of support for durable painting. On account of its very low cost it is sometimes utilized for students' class work in oil painting; for this use it is coated with a thin shellac size followed by a coat or two of flat wall paint. The easiest way to cut this material is to rule a line on both sides with a sharp knife and break it smartly over the edge of a table. When it is desired to split and separate the two sides of a piece of such board, as when sketches have been made on both sides, this can be done with a large, pointed bread-knife, the edge of which has been made somewhat sharper and smoother than is usually customary. Compo-board is a rather outmoded material made of a thin sheet of light-weight splintery wood faced on either side with sheets of brownish-red cardboard.

2. *Cellular or porous boards,* made in one homogeneous thickness. These

materials are bulky and loose in texture compared with the other boards; one of their functions is to serve as an insulating material in construction. They do not offer sufficient resistance against average wear and tear to serve as supports for permanent painting; furthermore, they are subject to much internal expansion and contraction, and they tend to become brittle on ageing. The most open-textured is Celotex, a familiar grey insulating board composed of cellulose fibres (from sugar cane) which have been rather loosely compressed and matted together by pressure alone. Celotex is said to contain no added binding material. Although it presents an interesting rough texture for some types of painting, experience proves that its structure is not dense or rigid enough for durability; furthermore, the material tends to become discoloured and brittle with age. Its web-like structure resembles that of a piece of paper viewed under the microscope.

3. *Compact boards.* Another and most important group consists of boards which are similarly pressed from fibres into one homogeneous layer, but which are of such close, compact texture that they are satisfactory substitutes for wood. The varieties selected here as durable are believed to be permanent; they have passed all tests except the one of actual time. They have not been available long enough for us to have absolute confirmation of the results of tests, but because they are superior to wood in withstanding accelerated test conditions, we accept them as permanent.

Presdwood, the most recommended board of this type, is a brown building board $\frac{1}{8}$ inch thick, perfectly smooth on one side, criss-crossed as with the marks of a wire screen on the other. Made in Sweden and marketed by Messrs. Masonite of London, it is sometimes marked Genuine Masonite Presdwood.

This material contains no binder, but is made by exploding wood fibre under a steam pressure of 1000 pounds per square inch, and pressing the refined pulp with heat. The fibres interlock and form a permanent hard mass, evidently bound by natural lignins or other ingredients of the wood.* During the process the fibres are impregnated with a very small amount of sizing compound made of paraffin, which imparts a water-proof quality to them; the finished boards are moisture-resistant to a high degree and will not warp readily. Large pieces will, of course, curve and bend by their own weight if left standing on edge, but this does not occur when they are properly framed or braced, and it usually does not occur at all in the case of unframed pieces shorter than 24 inches. Presdwood is sold at timber yards and builders' merchants in sheets 4 feet wide and in several lengths up to 12 feet. Additional details of its properties and uses will be encountered in the following pages where the application of grounds to panels is discussed. I have used this material since its introduction; along with many other painters, I have come to regard it as an entirely reliable material and, under the average conditions, superior to wood as a support for easel paintings.

Other products of this company which are not recommended for the

* Boehm, R. M., 'The Masonite Process.' *Industrial and Engineering Chemistry*, Vol. 22, No. 5, May 1930, p. 493.

same purposes, but which may be used for other purposes, according to the judgment of the user, are $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{5}{16}$ inch Presdwood, which are the same material in thicker forms, useful for small panels which are not intended to be cradled. They are rather unnecessarily heavy and clumsy for most of the other purposes mentioned in this book; they have little advantage over the $\frac{1}{8}$ inch variety when that is properly backed and framed. A thinner grade ($\frac{1}{10}$ inch thick) is also made. *Masonite*, a loosely textured insulating board of the same brown colour, belongs in the second class of materials, as mentioned on page 193. Gesso panels made on this material are likely to crack because of its internal movement, and their edges will become battered and frayed during normal use. It has a loose-textured, cellular structure, and it exhibits all the faults of such materials when used as a support for painting grounds. This Masonite insulating board contains the same ingredients as Presdwood but does not receive the final pressure that welds the Presdwood fibres into such a compact mass. *Tempered Presdwood*, sold in the same thicknesses as the regular Presdwood, is made in two colours, a brown darker than that of the regular, and a black. It is impregnated with an oil which makes it very tough and resistant to wear. It is to be avoided for use in gesso panels, as the permanence of adhesion with such an oily base as well as the permanence of the oily material itself, is doubtful. *Quartrboard* is a variety intermediate between Presdwood and Masonite, and experience shows that it is not dense or durable enough to serve as a support for permanent painting.

4. *Other boards.* Numerous other types of boards used in construction work are of less interest to the painter; gypsum or plaster boards are made of a layer of plaster faced with cardboard or paper layers, and rather heavy boards are made of asbestos fibre bound with cement and pressed for compactness. The usual mixture contains about 80% Portland cement. Asbestos boards are painted with oil paint in industrial practice, but for permanent results they are too alkaline to be used for oil or tempera; however, they are suitable for casein and other mural purposes.

The literature of the industrial wallboard field is scant, and most of the information we have on these products is supplied by the makers. The other competitive close-grained homogeneous materials are believed to be made with added oily, aqueous, or resinous binders, and although some of them may be equal in value to those mentioned here, I do not know of enough practical artists' tests over a sufficient period of time to recommend them.

Cradling of Wallboard Panels. The cradling of panels by attaching wooden strips to their backs with strong adhesives, is designed to increase their strength, rigidity, and durability, to counteract their tendency to warp, curl, or split, and to rectify such defects in the case of old paintings. The term is perhaps more accurately applied to the specific criss-cross method of conserving wooden panels described on page 354, but it has recently come into general use in reference to any method of bracing panels by fastening wooden or metal strips at the rear.

Panels made of Presdwood or similar material, which, unlike wood panels, neither split nor become permanently warped, are ordinarily made

rigid by gluing the cradling on all around without any provision for loose strips. The usual backing is wood of the same approximate size and quality as the heavy stretcher strips used for canvases; a rectangular frame with two crossbars, horizontal and vertical, is generally employed for the sizes up to 25 × 30 inches. Larger sizes usually need more bracing; the cross-members of a very large support are often made as close as 12 inches apart, but the spacing may vary and is a matter for individual judgment.

The use of regular canvas stretcher-strips with the bevelled edges planed down is a makeshift; much better panels are made if the frame or cradling is specially constructed for the purpose. The corners should be mitred and the joints be dovetailed or dowelled by any of the regular methods. The ends of the crossbars should be mortised into the sides. Any good carpenter, amateur or professional, can make such frames from selected, well-dried timber.

After the cradling is completed the edges of the Presdwood, which usually are somewhat ragged from the sawing and subsequent handling, may be made neater by finishing them off with a coarse file, or rasp, and sandpaper. The ground is less likely to chip off at the edges if they are bevelled or rounded. Small Presdwood panels, up to 24 inches long, are sometimes coated with gesso on one or both sides and left uncradled, especially for sketching and other temporary purposes; but for the very best permanent painting this procedure is not to be recommended even for the smallest sizes.

It is useless to attempt the cradling of panels without employing strong cabinet-makers' clamps or a press of some sort; the piling on of weights is a makeshift and an unreliable method. Unless the panel is firmly clamped to the wooden strips so that they are in contact at all points and the glue is under pressure during the time it is setting, bad warping, separation of the panel from the cradling, or some movement which cracks the ground, usually occurs. The best and most convenient adhesive is the prepared casein cement described on page 279.

The use of nails and screws is a doubtful expedient. They may be utilized in repairs, or to reinforce suspiciously weak spots, but their general tendency (according to my experience with defective panels of my own, with those made by pupils, and with commercially made products) is to give way or pull out erratically, thus subjecting the panel to a twisting warp, with disastrous results to the ground. It is a simple matter to countersink the screw and nail heads and fill the spots flush with the surface with a plastic material; but it is almost an impossibility to keep these spots permanently invisible. Iron and steel will rust, and copper and brass will corrode by electrochemical action, thus discolouring the gesso, and it is extremely difficult to prevent this by any means. The plugs will shrink, swell, crack, or fall out—at any rate they remain weak spots. The greatest danger from the use of nails and screws, however, is the unequal tension produced on various parts of the painting.

Pictures on wooden or wallboard panels should be well braced and supported by their frames in order to resist warping, but no panel should be so tightly held by a picture frame that expansion will produce buckling. See *Framing Pictures.*

Gesso Grounds

After the selection and preparation of a support for the panel, the next operation is to coat the panel with several layers of a white gesso. Gesso is a plastic or liquid material applied as a coating to surfaces in order to give them the correct properties for receiving painting, gilding, or other decoration. It is made by mixing an inert white pigment such as chalk, whiting, or slaked plaster of Paris, with an aqueous binder such as solution of glue, gelatin, or casein (see page 432). Gesso may also be built up, moulded or modelled into relief designs, or carved. Apart from its use in preparing flat surfaces or grounds for painting, it is employed in the decoration of picture frames and furniture, and to a lesser extent as a medium for modelling. When finally dry, its surface is normally sandpapered to a smooth, ivory-like finish.

Although gesso is sometimes applied to canvas, especially to the back of prepared oil canvases by some painters, its lack of flexibility makes the survival of such grounds extremely doubtful. When the gesso is carefully applied in two thin coats, the first one scraped down wet as in the preparation of an oil canvas, it will adhere well and seem to be quite stable but will often develop a fine, all-over crackle within a comparatively short time.

Ancient paintings on gesso grounds over canvas supports are usually covered with a dense, all-over pattern of fine crackle; provided that pieces have not become loosened or flaked off, this is seldom considered a bad defect but is accepted as the normal effect of age. Such crackle on a recently painted picture, however, is entirely undesirable, and the use of gesso or some of the absorbent semi-gesso or emulsion grounds on canvas entails this risk; it is not unusual for aqueous grounds on canvas to show signs of crackle soon after completion and to exhibit serious cracking within a comparatively short time after the painting has been completed. Rigid panels are the best support for gesso grounds.

As any artist who has become adept by the repeated preparation of gesso ground knows, the unerring production of perfect gesso surfaces requires careful workmanship and a painstaking attention to detail. Because of the narrow limits of the required properties, recipes for gesso are rather delicately balanced, and for this reason complete instructions for its mixing and application seem complex, although gesso itself is simple both in principle and in substance. The common variations encountered in different samples of glues and casein (because of differences in age, atmospheric conditions, and sources) as well as variations in the properties of the pigment used, are not infrequently sufficient to throw published recipes off balance and make the coats prepared according to them too hard or too soft and the liquid too heavy or too thin. The experienced worker is careful to observe such variations, especially when changing his source of supplies, and will regulate hardness and brushing quality in his mixtures, and he will apply simple tests or trials to his materials as he goes along.

Defects of Gesso Panels

Pinholes are caused by minute air bubbles which appear while the gesso is drying. They usually develop in the first coat; once started, they persist throughout subsequent coats. Tempera or oil colours applied over a surface pitted with pinholes will magnify their effect rather than conceal them. One of the reasons for the development of pinholes in an otherwise well-made gesso panel is the way in which the first coat is applied—often the gesso has not wet the support thoroughly because of dust, temperature variations, or high surface tension in the gesso mixture. Careful application of the first coat, as described in the following methods of procedure, will ordinarily eliminate this defect. Pinholes may often be the result of or may accompany other defects cause by application in cold or damp rooms, as mentioned later.

Pinholes will develop if the glue solution is too dilute, and may sometimes also develop if it is too concentrated. Undue beating or whipping just prior to use will obviously cause air bubbles or foaming, especially in hot glue gesso. The surface tension of the gesso may be reduced and the formation of pinholes made less likely by the addition of alcohol, but this is by no means a safe procedure when the gesso is to be used on panels, as it may lead to other defects; it is recommended by some craftsmen for picture-frame gesso, especially in cold weather, but is not generally approved for panels used in permanent painting. Alcohol should never be added to casein gesso. The addition of oxgall to subsequent coats will often eliminate or minimize pin-holes which have started in the first coat; this is apparently a safer method.

Any cracking, peeling, or blistering of the gesso will generally occur as soon as the coating is thoroughly dry; one of the generally accepted statements on the advantages of correctly made gesso panels (and tempera paintings as well) is to the effect that if the thoroughly dried coating shows no evidences of the development of these defects within two weeks, it is a pretty safe conclusion that such defects will not occur. However, it may be added that should any slight evidences of cracking be discerned it is practically certain that these will eventually develop into complete cracks.

Cracking and peeling away of the gesso is commonly caused by too concentrated a glue solution, by too much variation in the strength or composition of the several layers (especially by strong gesso over weak), or by highly unfavourable atmospheric conditions. Although this last cause is a frequent one, I do not recollect seeing it mentioned in published accounts. It has been shown by experience and experiment and research that those oil films which have the most rapid and uniform rate of drying are the most durable, the toughest, and the least likely to crack; it is in this respect that linseed oil is superior to poppy and other drying oils. The same rule seems to govern the drying of gesso. In poorly heated places in the winter, and in cool, exceptionally damp places such as basements, rooms with freshly plastered walls, etc., where drying is greatly retarded, I have seen examples of completely ruinous cracking of gesso panels which had been otherwise well made

by experienced practitioners who had no such failures when their panels were made in reasonably dry and normally warm surroundings.

When the glue solution is too dilute it will produce a weak, soft gesso, as undesirable as the over-hard surface produced by too concentrated a glue solution, but such a surface will not ordinarily crack; however, if the solution has been very greatly over-diluted, a mottled crackle will appear, usually not in the form of open fissures.

As in the application of any ground or paint coating, there must obviously be a good bond between the coating and the surface to be coated; the support must be sufficiently coarse-textured or absorbent to afford an adequate key for mechanical bonding of the gesso, and it must be free from all traces of oil or grease. The cracking and separation of gesso due to lack of proper qualities in the support is easily identified by a clean parting of the ground layer from the support.

Cracking after coatings have been applied to the finished gesso surface is sometimes attributable to the use of too concentrated a glue, casein, or varnish size, which has penetrated the gesso and upon drying has contracted with enough power to crack the gesso and cause it to separare from the support. This is more likely to occur when the binder used in the gesso is too far outside the limits of correct practice (too dilute or too concentrated), or when adhesion to the support is insufficient. It seems to occur more frequently with casein glues than with hide or skin glues, and after such panels have been subjected to their first appreciable climatic change.

Preparation of Gesso

The Ingredients. The best record of the early European methods of making gesso is contained in the treatise of Cennino Cennini,[7] which describes the making of a glue from parchment scraps, and its combination with an inert white pigment; the latter was made by thoroughly slaking plaster of Paris in water until its cementing or setting properties (definitely undesirable in this case) had disappeared, the resulting product being an inert white powder (see page 324).

Today the best glues are sold under the names of rabbit-skin and calf-skin glues. Glues are made from the skins and bones of animals; skin or hide glues are very much more suitable than bone glues for our purposes, the optimum being a glue which will set to the strongest jelly, for with this kind the amount of organic material in the gesso is kept to a minimum.

The highest grade gelatin made from the skins, hoofs, and bones of calves is a pure, comparatively uniform product which has been much used in gesso, especially in preparing foundations for gilded picture frames and for furniture. Edible gelatin such as the powdered material sold in grocery stores has a yellow colour and is comparatively weak in jelly strength. The kind which is made for laboratory and technical use is obtainable in very pure water-white grades mostly imported from France and Belgium.

The ingredients of gelatin are not present in the same proportions as they

are not reliably so; but in order for most of them to enter into reactions, the proper conditions must be present. When two stable, inert pigments containing elements which are theoretically capable of reacting on one another, are mixed, it is often the case that on account of the stable, inert character of the pigments there is no danger of such actions taking place, because the conditions necessary to the reaction are absent. On the other hand, certain otherwise inert materials may be extremely sensitive to such mutual action. No indiscriminate rule may therefore be made, but the characteristics of each pigment or other material must be learned.

The carbonates and the sulphides of metals are all extremely sensitive to action by mineral acids; the oxides are inert substances more often than not. The salts of many metals and groups of metals have general properties in common, such as colour. Most crystalline salts of nickel are green; those of copper, blue; and those of cobalt are rose-coloured, changing to blue when they are made anhydrous. Chromium was named for its varied colours; all of the compounds of this metal are highly coloured. Zinc and aluminium compounds are white or colourless; very slight traces of iron impart a yellowish colour to a solution or composition. These general remarks on colour do not apply to compounds which contain more than one metallic element.

Sodium and potassium are two very similar elements, whose compounds are closely allied. From the viewpoint of technical uses, a broad general statement is that a potassium compound is more active and will give somewhat better results than its analogous sodium compound, but the less expensive and more available sodium compound is usually adequate for the purpose. There are occasional exceptions to this statement; sometimes one compound is entirely unsuited to a reaction which calls for the other, and sometimes the two will give distinctly different results.

Valence. Atoms of an element may be graphically imagined to have a certain number of arms or hooks by which they become linked to other atoms to form compounds. The number of such hooks an element has, is called its valence; for example, it will be seen in the formulas in the following pages that oxygen has a valence of 2, hydrogen 1, carbon 4, and the benzene radical a valence of 6. (A radical is a molecular group of two or more elements which often hangs together and acts like a single element during a reaction; the hydroxyl (OH), carbonate (CO_3), sulphate (SO_4), and ammonium (NH_4) radicals are familiar examples.) It should be clear that these arms, links, bonds, etc., are theoretical descriptions of behaviour, not tangible items. Valence can be more scientifically defined as the number of hydrogen or chlorine atoms with which an atom of the element in question will combine, the valence of hydrogen and chlorine being 1.

Some elements are polyvalent, that is, they have the ability to form perfectly normal and saturated compounds in more than one proportion; for example, iron, as in the oxides previously mentioned, has a valence of 2 and 3, depending upon the conditions under which the combination occurred.

Nomenclature. The names of the elements were derived from a number of sources. The elements which were known in very early times or whose pro-

minent compounds were known have names which come from basic roots of the various languages; those more recently isolated were named (in Latin or Greek form) for their properties, their compounds or sources, or in honour of their discoverer or the land where they were discovered.

Binary compounds (those which consist of two elements) customarily take the name of the more definitely metallic or electrically positive element, followed by the name of the more negative element with the ending *ide*. Sodium sulphide is a compound of sodium and sulphur; zinc oxide, of zinc and oxygen. Some elements may function in both ways. For example, chromium occurs in the usual oxides and salts (chromium oxide, etc.); it also exists in a series of acid compounds—chromic acid and its salts, which are called chromates.

A substance that can be identified as the salt of a normal acid is named after the metallic constituent followed by the acid name ending in *ate*. Sodium sulphate (Na_2SO_4), for example, is the sodium salt of sulphuric acid (H_2SO_4); it can be made by the reaction of sulphuric acid and a sodium compound. Sometimes the significant elements of two acids are identical in kind but different in number. The salt corresponding to the acid with fewer atoms to the molecule takes the ending *ite*; sodium sulphite (Na_2SO_3), for example, is the sodium salt of sulphurous acid (H_2SO_3). The endings *ic* and *ous* are employed to designate numerical variations in an acid or oxide; the molecules of the *ous* compounds have fewer atoms or a smaller proportion of oxygen than do those of the *ic* compounds.

Generally the acids, and most of the salts, which end in *ous* are the more unstable, and those which do not contain their maximum complement of atoms are called unsaturated. Some of them will take up additional atoms with avidity; others will freely disintegrate or give up their atoms. This is not to say that the *ous* compounds are always unstable or unreliable as regards permanence; for instance, the ferrous (iron) oxides are as thoroughly inert and permanent pigments as we may desire, and would require the most drastically severe chemical conditions or extremely high temperatures to be altered.

Further designations are given to compounds for other reasons, which are often self-evident. The prefix *hyper* is applied to the numerically highest in a series of compounds; the prefix *hypo* indicates the lowest. The prefix *per*, as in peroxide, perchloride, etc., denotes the higher of two compounds—usually the higher in valence as distinguished from the first, lowest, or mono form. The prefix *proto* is obsolete; it referred to this lower form. *Thio* means sulphur-bearing.

Other prefixes referring to numerical variations are *di* (or *bi*), *tri*, *tetra*, *sesqui*, etc. *Meta*, *ortho*, and *para* refer to variations in arrangement.

Oxidation. The chemical combination of a substance with oxygen to form an oxide, is the commonest reaction in nature. When a substance burns it oxidizes; combustion is defined as rapid oxidation with the accompaniment of heat and flame. An example of slow oxidation is the rusting of iron. Iron oxide for use as a pigment, however, is made by the calcination (roasting) of

an iron salt, where by close control of the process a number of shades and hues can be produced.

Some oxides may be reconverted to the original metal or from the *ic* to the *ous* form by reduction, which may be considered a reverse process. In chemistry, the terms oxidation and reduction are sometimes applied to reactions not involving oxygen, where a substance is changed from a numerically higher atomic form to a lower, or vice versa.

Polymerization. Polymerization occurs occasionally in artists' materials and processes; it is a reaction where nothing enters into or leaves a compound but where the change is internal and the atoms become rearranged, condensed, or joined in a different pattern, altering the properties of the substance as definitely as they are altered in any other chemical reaction. The term is rather loosely used in this book and in most other technical accounts, to describe changes which may be complex reactions involving other considerations at the same time.

Catalysis. A catalyst is a substance which assists in the production or acceleration of a chemical reaction without itself entering into the reaction.

Hydration. Some compounds, especially oxides, exist in a form where the hydroxyl radical (OH) is combined with them; they are not pure or simple hydroxides, but 'hydrated oxides'. Such materials can be reduced to the pure oxide form by subjecting them to heat. This process involves a chemical change and is not to be considered a mere driving off of water; the temperature required is usually quite high.

Water of Crystallization. Many salts occur in more than one structural form in combination with water. Thus the transparent blue crystals of copper sulphate, although perfectly dry to the touch, contain 7 molecules of water to each molecule of the salt, and the chemical formula is written $CuSO_4.7H_2O$. If the crystals are heated, the water is driven off, and anhydrous $CuSO_4$ (a white powder) is the result.

Hydrolysis. This is a chemical reaction caused by the action of water; it results in the decomposition of a salt to produce a new substance.

Solubility. Solid substances are soluble or insoluble in water and other liquids to varying degrees; tables are published in chemical handbooks, listing the solubilities of all chemical compounds. With few exceptions, heat increases and cold diminishes the solvent power of a liquid. A solution which contains as much of the solid material as it will hold at normal room temperature, so that further addition would not go into solution but would remain in the liquid as undissolved matter, is called a saturated solution. When a liquid is heated so that it will dissolve more than this normal amount of solid, and is then cooled to room temperature, the additional amount of solid will fall out or crystallize, and the resulting liquid will be a saturated solution.

Absorption and Discharge of Moisture. Some crystalline substances have the property of losing their water of crystallization when exposed to dry air; sal soda is an example. This property is called *efflorescence.* Others, notably calcium chloride, alcohol, and lye, will absorb moisture from the air. Such materials are called *hygroscopic*; and if the affinity for water is so great that

the substance becomes spontaneously dissolved or wet, the property is termed *deliquescence*. The same terms are used to denote the same properties in non-crystalline materials.

Allotropic Forms. When an element exists in more than one form, as regards superficial physical or structural properties, these variations are called allotropes. The various forms of carbon, e.g., lampblack, diamond, graphite, etc., are familiar examples.

Symbols. In the early days of chemistry the cabalistic symbols of the alchemists which were employed ceremonially (as much to mystify the layman as for any other reason) survived for a while, as a sort of shorthand or convenient method of representation. With the scientific development of chemistry, a universal system of shorthand designations for the various elements and their reactions came into use.

An atom is represented by the initial letter of the element. Where more than one element has the same initial, another significant letter is added in lower case; thus, C is carbon, Cl is chlorine, Cd is cadmium.

Chemical Formulas and Equations. A chemical formula expresses in concise form the number, proportion, kind, and arrangement of atoms in one molecule of a substance. A chemical equation expresses the reaction which takes place between two or more substances and the resulting redistribution of the atoms in mathematical balance, according to atomic theory and other laws. An example of a chemical equation, that involved in etching, is:

$$\underset{\text{3 parts of copper}}{3Cu} + \underset{\text{8 parts of nitric acid}}{8HNO_3} \rightarrow \underset{\text{3 parts of copper nitrate}}{3Cu(NO_3)_2} + \underset{\text{2 parts of nitric oxide}}{2NO} + \underset{\text{4 parts of water}}{4H_2O}$$

The coefficients, or large numbers preceding the symbols, refer to the number of molecules or parts by weight of each substance which will complete the reaction according to the law of definite proportions; they are like the figures in a recipe. The small sub-numbers refer to the number of atoms of the element which combine to form a molecule of the particular substance; these are fixed and invariable for each substance. The group of symbols enclosed in brackets is the nitrate radical previously mentioned. Its valence is 1; the valence of copper is 2; therefore, two of these nitrate groups are combined with one atom of copper, and the brackets in this particular case indicate that the subscript 2—the small figure below the line of the letters—qualifies the entire group.

If the numbers of atoms of each element, as indicated by both the coefficients and the subscripts, are added, they will be seen to check, or balance, on each side of the equation. For instance, there are 24 atoms of oxygen indicated for the nitric acid, and the total on the right-hand side of the equation is also 24: 18 in the copper nitrate, 2 in the nitric oxide, and 4 in the water. Matter is indestructible and all the ingredients which enter into the reaction must be accounted for.

In the actual etching process, considerable water is also present, but although it makes possible the particular reaction, it does not enter into it, and so is ignored in the equation. The copper nitrate dissolves in the water as

soon as it is formed, the NO passes off as a brown gas, and the copper is apparently eaten away. The colour of copper nitrate is green; if we saved the greenish solution instead of pouring it out, and boiled off the superfluous water, we could obtain crystals of copper nitrate, which in turn could be reduced to pure metallic copper. Without the water, a somewhat different reaction would occur.

As a matter of fact, the above reaction is a rather complex one. The left-hand group shows the beginning, the right-hand group shows the result, but the reaction actually occurs in two stages, and should be represented by two formulas, were we interested in following up its theoretical aspect rather than its practical application.

Organic Chemistry

Compounds of the element carbon are so numerous and arranged into groups and series of such complexity of structure and behaviour that their study is treated as a branch of chemistry separate from the study of the inorganic compounds that have been discussed heretofore in this section. There is no precise line of demarcation between organic and inorganic chemistry; the simpler compounds of carbon, as well as those in which carbon is not a significant constituent, are generally studied and considered in connection with inorganic chemistry.

Originally the term organic was applied to all substances of animal and vegetable growth, and the term inorganic to those of mineral origin; and although many organic compounds have long since been manufactured synthetically, the original distinction still influences our understanding of the subject, and it is a good enough rough idea of the matter, especially for purposes of technical application.

One's general impression of such distinctions is influenced largely by typical or majority examples. One becomes accustomed to identifying organic products of vegetable or animal origin with the characteristic attributes of such matter as compared with the dead or inanimate nature of inorganic materials. We infer that organic products have a definitely limited life span, are more flexible, yielding, or malleable than inorganic materials, and more subject to decay on ageing and exposure to adverse conditions. Such a viewpoint is generally correct; but on the other hand, the number of inorganic substances of mineral origin which can be used in the arts is also limited. When one thinks of mineral substances, the first picture in one's mind is usually that of rocks and other durable, inert materials; as a matter of fact, large categories of inorganic substances, natural and artificial, are among the most unstable and violently reactive materials that exist. The organic products in approved use in the arts, while not in a class with granite or cast iron, are nevertheless adequately durable for the purposes for which they are intended and the conditions under which they are expected to survive.

Such natural organic products as are used virtually in their native states, as resins, gums, oils, etc., are not single, definite chemical compounds, but

loidal realm lies somewhere between the smallest particles visible through an ordinary microscope and the largest molecules; the largest molecule is supposed to measure much less than 1 millimicron. A colloidal solution may also be considered as halfway between a true solution and an ordinarily coarse or filterable suspension.

The tremendous extent of increase in surface produced by such minute subdivision is not always realized, but this magnification of surface area and the consequent predominance of surface phenomena is considered the chief element governing colloidal behaviour. If a cube measuring $\frac{1}{4}$ inch were subdivided into particles of the minimum colloidal size, the surface area would be multiplied by the million and would total somewhere in the neighbourhood of an acre.

A familiar example of the changes in properties caused by increase of surface is the well-known spontaneous combustion of rags, cotton waste, etc., when such materials are soaked in drying oils. Normally the oxidation or drying of linseed oil by the absorption of oxygen from the air is a mild and slow reaction, and no change in temperature can be observed; but when the oil is spread over such a finely divided substance, and is exposed to the atmosphere over such a widely extended surface, the heat developed by the reaction is so greatly magnified that it may be sufficient to ignite the materials.

Returning to our example of a colloidal solution of glue or gelatin, we find that the heavy, viscous, liquid form of this two-phase system may be transformed to another colloidal form, that of a jelly, by allowing it to cool. The transformation in this particular case is reversible; that is, the gel may be transformed back to the liquid or sol form by warming it.

It has been found that with certain two-phase systems of dispersions, not necessarily entirely of colloid dimensions—for example, in certain paints which are dispersions of relatively coarse pigments in oil—similar changes in consistency may be produced by merely shaking, stirring, or otherwise disturbing the equilibrium by mechanical means. This phenomenon has been called thixotropy, or change by touching. The theory has of recent years been applied to paints and explains certain hitherto unaccountable actions. For example, when certain mixtures of ultramarine and oil, ground to produce a stiff paste, are re-ground, stirred, or agitated, they become liquid or stringy; on being allowed to rest, they go back to the paste or buttery form. Certain heavy viscous paints which have thixotropic properties will, upon being brushed out, become fluid, causing the paint to brush easily and level out free from brushmarks.

Colloidal phenomena also contribute to the drying of a linseed oil film, to the action of lithography, the behaviour of pigments in mediums in general, and the making and use of emulsions.

Molecular Cohesion or Adsorption. The familiar word absorption which refers to the imbibing of a liquid by certain spongy or loose-textured solids through porous action, is not the same as the term adsorption, which is used to indicate the adhesion of a liquid, gas, or solid to the surface of another solid by molecular attraction.

Adsorption may be pictured as a sort of freezing or gluing on of a substance; an adsorbed layer of a material is usually held so strongly that it cannot be washed away with liquids that would ordinarily dissolve it. Gases, liquids, and solids are adsorbed equally. In the past, the term has been used mostly to describe the adsorption of gases. According to present theories, only matter whose molecules arrange themselves in a certain pattern will form adsorbed layers. The molecules of such matter have their axes parallel, all pointing in the same direction, and are described as being oriented or polarized. As previously noted, the internal structure of molecules, which we have disregarded in this account, has much to do with their actions. Adsorption in itself is not a chemical action but its occurrence is usually dependent upon some chemical reaction.

Emulsions. Emulsions are described in outline in the section on tempera painting. In order to produce an emulsion by mixing oil and water, which ordinarily are immiscible, a third substance—namely, an emulsifier or stabilizer—must be present. Some of the raw materials, which are employed for the desirable properties they impart to the finished emulsion, are in themselves very good stabilizers; other combinations of oily and aqueous solutions will not readily enter into stable emulsions without the presence of an additional stabilizer. The words oil and oily in this connection are meant to include waxes, fats, and resins.

An emulsion is a colloid or two-phase system, but all liquid colloidal solutions are not emulsions. Egg-yolk is an emulsion, the tiny globules of egg oil being dispersed in the watery ingredient. Egg-white is not an emulsion, since it contains no such dispersed oil droplets; it is simply a colloidal solution of albumen in water. A casein solution by itself is not an emulsion. But both of these colloidal solutions will readily form oil-in-water emulsions when shaken up with a vegetable oil.

A second type of emulsion also exists, the water-in-oil type, an example of which is butter, where the water is dispersed in tiny globules throughout the butter-fat, which acts as the dispersing medium. Such emulsions are evidently formed when the stabilizer is in colloidal solution in the oily rather than in the aqueous liquid. This seems to be the case when resins, water-insoluble or metallic soaps, or finely divided pigments in suspension, act as the stabilizer, rather than when water-soluble stabilizers are present.

When emulsions contain a heterogeneous collection of ingredients which contain both the hydrophile (water-affinity) and lipophile (oil-affinity) types of stabilizers, systems recognized as dual or multiple emulsions are likely to be set up; in these, the little globules of the dispersed liquid act as a continuous phase for still tinier droplets of the dispersing liquid within them. As many as five such systems within each other have been detected in microscopic examinations of such emulsions.

The dispersed drops of oil in an oil-in-water emulsion are understood to be surrounded by adsorbed films of emulsifier, but these do not protect them from breaking up under certain conditions. By the addition of enough emulsi-

fier of the opposite type, an otherwise stable and balanced oil-in-water emulsion may be transformed or inverted to a water-in-oil emulsion, the dispersed drops expanding into a continuous medium and the dispersing medium contracting into globules.

The amount or proportion of oil has little to do with this difference. Some oil-in-water emulsions contain very little oil, with the globules spread through the mass in a sparse manner; others can contain more oil than water, and still be of the O/W type, the globules sometimes being close-packed or jammed together in such a way as to distend or compress their shapes without its disturbing their adsorbed layers or skins. The same is also true of the W/O type. The subject is discussed further in connection with tempera emulsions in the second part of this section (page 318).

The study of emulsions and their applied technology comes somewhere near the head of the list of those branches of chemistry which are in an incomplete state of standardization or establishment, and a knowledge of physical chemistry and its mathematics would be required to attain much more knowledge of the subject than the inkling here presented. Most of the definitely accepted theories are of comparatively recent establishment.

Part Two: Practical Applications

The first thing to be borne in mind is that many of the artist's raw materials—oils, resins, gums, glue, casein, eggs, etc.—are natural products. This means that they are highly variable mixtures and concoctions of a number of things and so cannot be expected to exhibit exactly standard or uniform behaviour in chemical reactions as do the simple, pure substances discussed in the first part of this section. Second, with few exceptions, the chemistry of these products is not at all well established and in many cases even where materials and processes have been standardized and put under chemical control, we have, after decades of scientific study, little conclusive evidence regarding their underlying principles, particularly as they are applied to artistic painting.

A good deal of the best work on the chemistry of natural raw materials which are used for painting has been done either in industrial laboratories or by men who have approached the problems from the viewpoint of industry. This has directed research into channels not directly in line with the application of results to artistic painting, because the commercial or industrial value of these products as artists' materials is insignificant as compared with their commercial value in other uses.

There has long been an obvious need for a systematic standardization of artists' materials on a rational basis, along the lines of such rigid specifications as govern the selection of materials used by the British and various United States Government departments, the railroads, and the great industrial corporations. In these instances the standards are based on correct practice as established by experience and by research carried out for the purpose. In the past, the few attempts to establish such standards for artists'

materials have not proceeded very far;* organization of such an undertaking requires the proper sort of leadership. The standards should be set up by practical experienced artists and technicians rather than by theorists in each field; they should be independent of the bias of the manufacturers of materials, but at the same time there must be an element of justice to reputable manufacturers and due consideration of availability of supplies and the problems of distribution.

Just at present a move in this direction is being made in America under the auspices of the United States Department of Commerce, and standards of quality for artists' oil colours are being set up. Details of this work in its present state are reprinted on page 444.

Drying Oils

An oil, according to the broad and simple definition of general chemistry, is a glyceride of a fatty acid, a fatty acid being an organic acid which belongs chemically to a certain family or series of acids of similar constitution and reaction, the most important members of which occur in fats and oils of animal and vegetable origin. A glyceride is an ester or salt containing glycerin. This definition excludes such oily liquids as the petroleum or mineral oils and the essential oils, which are of different composition; these are called oils because of their external or superficial characteristics. It includes the fats; the vegetable oils are actually liquid fats. Vegetable and animal waxes are also included.

When we come to study the composition of the vegetable oils, however, we find that they consist of rather complex mixtures of a good many variants of these acids and esters with other materials, in varying proportions. The glycerides themselves are not simple esters, but triglycerides, that is, combinations of one molecule of glycerin with three of the fatty acid radicals, the latter occurring in every possible complexity of combination: they may all be the same acid, they may be two or three different acids, and the two latter combinations may appear in perhaps forty different types of arrangement. The glycerides in drying oils will combine readily with oxygen, as indicated by the fact that in their structural formulas their molecules are pictured as unsaturated; that is, their structure or arrangement includes double bonds or links which are able to combine with various numbers of oxygen atoms, depending upon the type of glyceride.

The drying properties of most oils are due to the presence of glycerides of linoleic and linolenic acids, which have the property of combining spontaneously with atmospheric oxygen to start a chain of reactions which end in the conversion of the oil to the tough, durable, insoluble film known as linoxyn. The action of moisture on certain of the glycerides of linolenic acid, particularly in the absence of daylight, is also one of the chief causes of the yellowing

* The British Standards Institution, by its constitution, is able to undertake the preparation of Standards only when requested by an authoritative body, either of manufacturers or consumers.

of oil films. Linseed oil has a larger percentage of linolenic acid and its glycerides than any other drying oil except perilla oil, which is a better drier, forms a harder, tougher film, and yellows much more than linseed oil. Compared with linseed oil, poppy oil contains a smaller total amount of these glycerides, and little or no linolenic acid, and this minimizes one of the causes of yellowing of its films.

However, because the presence of these constituents in sufficient amounts is necessary for an oil to dry in the proper manner to a tough, durable, non-shrinking, non-spongy film, the inferiority of poppy oil to linseed in this respect must be attributed to their absence. Other impurities in linseed oil, such as chlorophyll, the vegetable colouring matter which occurs in grass and foliage and becomes red, yellow, and brown as it fades, are a contributory cause of the yellowing of the oil film. They are not a principal cause, since they are almost entirely removed or destroyed during the process by which the oil is refined.

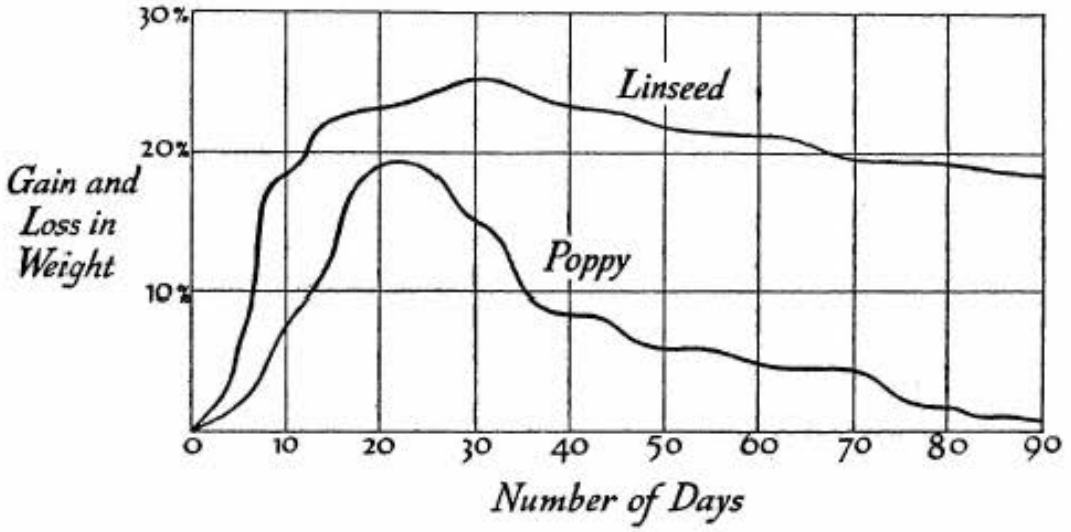
Several much-quoted letters written by Rubens[14] recommend exposure to sunlight for certain oil paintings which had in each case been boxed soon after being painted, and stored for some time. For centuries artists have known that freshly-painted oils should be exposed to daylight under normal conditions, that continual or severe exposure to bright, direct sunlight is not beneficial, and that the darkening of oil paintings from continued absence of light during the drying process is a reversible reaction which can be corrected by further exposure to daylight.

These facts have been substantiated in the twentieth century by a large amount of research by Eibner[74] and others, and considerable data on various reactions of the drying oils are on record.

The presence of normal or diffused daylight is necessary for the correct drying of an oil film, but any prolonged exposure to the direct rays of the sun is harmful, leading to cracking by reason of too rapid or violent drying action. A normal range of temperature and humidity, such as lies within the bounds of what are considered to be average, comfortable indoor conditions, is best. Excessive heat will accelerate and cold will retard the drying process; both are detrimental to the durability of the paint. After the painting has become completely dry, it will endure a slightly wider range of temperature and humidity, and should be altogether unaffected by the absence of daylight. Cracking may be caused by extreme and rapid loss or gain of weight in the oil film; the drying curves (see below) of linseed and poppy oils which have been subjected to abnormal conditions of temperature, sunlight, and humidity, will usually end in an abnormal loss of weight; the curves of poppy oil are always more exaggerated. An abnormally dry atmosphere will tend to cause more rapid drying and to show a curve which has abnormal characteristics; it is almost certain that this condition is detrimental to the life of the film. Even after oil paintings have become thoroughly dry, it is rather common knowledge that they should be kept in well-conditioned rooms, and that the dry air of some steam-heated rooms is injurious to them to almost as great an extent as is storage in a damp, unheated place.

Studies of the Drying of Oils. The drying curve is a means of graphically recording the changes which take place in the drying of an oil film; the vertical range indicates the percentage of gain or loss in weight, and the horizontal distance indicates the number of days of drying. It must be noted that in order to make a clear comparison an extremely good curve for linseed oil was chosen, and a rather poor curve for poppy oil, but the characteristic difference always exists in some degree. Eibner has recorded accurate details of such comparisons; the results of much similar work on linseed oil from an industrial rather than an artistic painting viewpoint, are also available in the scientific and technical journals.

The optimum behaviour for a drying oil is evidently for the curve to reach its height in the shortest possible time and for the decrease thereafter to be as small as possible. As indicated in the curves, the ultimate change in the linseed oil under normal conditions is small enough so that danger of



failure from shrinkage is at a minimum; the amount of change in the poppy oil is dangerously near if not beyond the bounds of safe practice. As noted under *Painting in Oil*, however, the manner in which the paint is used is probably the greatest factor in its success or failure in these respects. As shown by Eibner,[74] the drying curve of linseed oil is altered in a very harmful way by an abnormally damp atmosphere, and it is likely that a film dried in an abnormally dry atmosphere is likewise weakened, although not to such a great extent. Moist air retards and dry air accelerates the speed of drying. Drying in strong direct sunlight has an injurious effect on linseed oil and a worse effect on poppy oil. The action of various pigments with the oil, and also their mechanical effect on the structural strength of the film, are further factors in the success or failure of paints. This mechanical or structural effect may be roughly compared to the effect of sand in plaster, as explained on page 237.

The loss of weight in a drying oil film appears to reach its limit after two and one-half months with the average good oil, and, theoretically, varnishing

can safely be done after this point. However, this statement is based on laboratory tests where thin films of the pure oil without pigment are applied to glass, and conditions in an actual painting will vary so greatly from these as to make the results of such tests of little value as direct guides to practice. In general, I should say that it is better to varnish a painting a little too soon than to postpone the process indefinitely with the not uncommon result that the picture remains unvarnished and exposed to surface dangers for longer than was intended.

Yellowing of Oils. In all discussion of the yellowing of oil it must be understood, as Eibner and others have pointed out, that the matter concerns only clear oil films and the use of oils in techniques other than normal oil painting. In practical usage, correctly executed normal oil paintings do not turn yellow. The surface or protective coatings, dirt, and other removable or remediable conditions may cause browning or yellowing, but when the well-painted surviving examples of old oil paintings are cleaned of such extraneous matter, they are seldom if ever found to have suffered from yellowing of linseed, poppy, or walnut oil. It is only when the rules for correct procedure are disregarded, when inferior oils, poorly-compounded oil colours, or faulty methods of application are employed, that failures occur from this cause. The pigment in a well-formulated oil paint will mask any such slight changes; the proper dispersion of the pigment will prevent settling in the film or the formation of a layer of clear oil on top; and holding the oil content to a minimum and using the best kind of drying oil for the purpose will further safeguard the paint layer from yellowing or cracking.

Lithographic Varnishes. Lithographic varnishes, from which many types of inks for other printing purposes are also made, are heat-bodied linseed oils, very much like stand oils. A mixture of commercial litho varnishes of various degrees of viscosity will give results entirely different from those of a single, straight varnish of the required consistency, because many of the physical properties of an oil such as adhesion, levelling, tackiness, and wetting power, are appreciably changed and altered the more the oil is cooked and bodied. The mixtures will therefore consist of what we may consider different substances, or oils of different properties, rather than of merely heavy and light variants of the same oil. The thickening of drying oils is due to an increase or decrease in some sort of colloidal condition as well as to molecular rearrangement and oxidation. Recipes call for mixing various proportions of several litho varnishes, not because a single varnish of the required viscosity cannot easily be made, but because such mixtures will give different results.

The difference between a stand oil and a litho varnish is not very great, but stand oils especially prepared for paints will give better and more certain results, and litho varnishes should not be substituted for them. Litho varnishes are often set on fire for a while, as part of their process of manufacture; these burnt oils can be distinguished from stand oil by their odour.

Acid Number. Oils and resins are, as previously defined, variable mixtures of highly complex organic chemical compounds, among which are acids or compounds of an acid nature which are capable of reacting chemically with

alkalies under the proper conditions, although they are not strongly reactive substances as compared with the familiar mineral acids. For purposes of classification and comparison, and as an index of technological behaviours, an established, standard laboratory method of measuring the total amount of such reactive compounds is used; the result is expressed in figures termed the acid number. Refined linseed oils of low acid number usually run about 1 to 3, paint-grinding oils from 5 to 10.

Iodine Value. The term iodine value, which is often encountered in descriptions of oils, fats, and waxes, refers to the result of a standard laboratory test. The unsaturated fatty acids of these materials will absorb iodine; the iodine number is the percentage of iodine absorbed; hence it signifies the proportion of these fatty acids, and its magnitude is an indication of the purity and film-forming or drying quality of the oil.

Perilla oil is the only one of these materials which has a higher iodine number than linseed, some samples of it running over 200. Cold-pressed raw linseed oil has an iodine value of 177–189. Lewkowitsch[78] places walnut oil far down on the list, with an iodine value of 145, and poppy oil still lower, at 133–143.

Oil Index of Pigments

The following tables give details by which the list on pages 116–7 was computed

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	100 *Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
Aluminium Stearate	American	8	12·5	28	3·6	29
Aluminium Powder (pure aluminium, treated)	,,	21	4·8	16	2·1	44
Emerald Green	,,	28	3·6	13	1·7	47
Venetian Red (40% iron oxide)	,,	29	3·5	15	1·9	54
White Lead (basic carbonate, Dutch process)	,,	57	1·8	8	1·0	56
Spanish Red Oxide (native, 85% iron oxide)	Spain	37	2·7	13	1·7	63
Chromium Oxide Green	American	43	2·3	12	1·5	64
*Cobalt Green	Germany	44	2·3	12	1·5	65
Cobalt Violet	American	31	3·2	16	2·1	65
*Cobalt Violet	Germany	29	3·5	18	2·3	66

* Based on previously unpublished figures.

OIL INDEX OF PIGMENTS (*Continued*)

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	*100 Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
Zinc Oxide (French process, green seal)	American	47	2·1	12	1·5	71
Zinc Yellow	,,	28	3·6	20	2·6	72
French Ochre (native, 22% iron oxide)	France	24	4·2	25	3·2	76
Cadmium-barium Yellow, Light ($CdS + BaSO_4$)	American	35	2·9	17	2·2	76
Cadmium-barium Yellow, Golden ($CdS + BaSO_4$)	,,	35	2·9	17	2·2	76
Cadmium-barium Red ($CdS + CdSe + BaSO_4$)	,,	36	2·8	17	2·2	79
Cadmium-barium Maroon ($CdS + CdSe + BaSO_4$)	,,	36	2·8	17	2·2	79
*Naples Yellow	Germany	55	1·8	12	1·5	82
Indian Red (98% iron oxide)	American	43	2·3	15	1·9	83
Ultramarine Blue	,,	19	5·3	35	4·5	85
Titanium Dioxide (low absorption)	,,	33	3·0	20	2·6	87
Prussian Blue (C.P. Milori blue)	,,	15	6·7	50	6·4	96
Cadmium-barium Orange ($CdS + BaSO_4$)	,,	35	2·9	22	2·8	97
Alizarin Red	,,	14	7·1	55	7·1	100
Ivory Black (12% carbon)	,,	22	4·5	35	4·5	101
Raw Turkey Umber (native, 46% iron oxide)	Cyprus	26	3·8	30	3·9	103
*Cerulean Blue	Germany	40	2·5	22	2·8	112
Raw Sienna (native, 73% iron oxide)	Italy	26	3·8	35	4·5	118
Yellow Iron Oxide (95% Fe_2O_3)	American	32	3·1	29	3·7	119
Black Iron Oxide (98% oxides)	,,	40	2·5	25	3·2	128
Burnt Sienna (native 77% iron oxide)	Italy	29	3·5	35	4·5	129
Burnt Turkey Umber (native 53% iron oxide)	Cyprus	30	3·3	35	4·5	136

* Based on previously unpublished figures.

OIL INDEX OF PIGMENTS (*Continued*)

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	*100 Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
*Aureolin	England	43	2·3	31	4·0	174
Cobalt Blue	American	32	3·1	43	5·6	180
Lampblack (99% carbon)	,,	15	6·7	85–100	11–13	164–194
Carbon Black (99% carbon)	,,	15	6·7	85–150	11–19	164–284
Viridian	,,	30	3·3	60	7·7	233
*Cobalt Blue	Germany	30	3·3	69	8·9	270

* Based on previously unpublished figures.

The countries named under 'origin' in the above list refer to the source of the samples used; excepting Spanish red, arsenical cobalt violet, French ochre, the Turkey umbers, the siennas and carbon black these pigments are also produced in Britain.

DRIERS

The drying or the acceleration of the drying of oils by the addition of driers has been variously explained since the oxidation of oils was recognized early in the nineteenth century. The most convenient statement in the recent past has been that such action is catalysis, the drier acting as a starter or accelerator of the reaction without entering into it. Certain actions of paints and varnishes which contain driers, however, contribute to the theory that the reaction is more complex. It has been pointed out that all the salts which act as driers are those of polyvalent metals, indicating that the process involves a change from one form of molecular arrangement to another; the gelation of an oil film involves reactions of a colloidal nature which also have a bearing on the drier's action. If oil is painted out upon sheets of metal, it is well known that certain metallic grounds inhibit or retard its drying action, while others accelerate it; those substances which retard, such as zinc, are called antoxidants. Progressive drying is a term which has been applied to the continued action of a drier upon an oil film after its primary purpose (that of producing a solid film) has been accomplished; driers which display this characteristic to a marked degree have a harmful effect on the durability of the film.

Driers which contain lead or other materials which are sensitive to external conditions will impart the same colour effect to the final paint as though a lead or other susceptible pigment were used. Driers are, as a general rule, more satisfactory in artists' paints when put into solution and added to

the finished oil or medium than when cooked into the medium. The normal drying action of a pigment which produces satisfactory films with oil, such as white lead or umber, is very much more desirable than the action of liquid driers.

Colours which have been ground in poppy oil require more driers than linseed oil colours to accomplish the same effect, but because the poppy oil film is less durable than that of linseed, excessive amounts must be even more carefully restricted. Manufacturers of prepared artists' oil colours add driers to some of the slow-drying pigments, but the careful maker holds these additions to a minimum, the aim being, not to make all the pigments dry in the same length of time, but to bring the rate of the very slow driers closer to that of the rest of the palette.

Resins

The composition of resins varies considerably; those usually classified as balsams and also a few of the 'gum resins' contain benzoic and cinnamic acid; rosin is largely abietic acid and a substance called resene. Resene appears to be the ingredient which imparts durability to the harder resins. The harder copals, damar, and sandarac consist of their particular characteristic resin acids plus resene; gum Thus and the other pine exudations have a more complex composition, containing these materials plus volatile oils and some resinates (esters of resin acids). The synthetic resins are miscellaneous products of a dozen different origins; most of them are of a very complex nature.

Turpentine

Turpentine and the other products of pine distillation, such as wood turpentine, pine oil, dipentene, and terpineol, have the property of polymerizing upon ageing, and passing into other heavier, more viscous forms which are less volatile and usually have a less agreeable odour. The action is more rapid in the presence of sunlight, air, and moisture, and it is usually accompanied by oxidation. This is the reason fresh materials are always recommended, and are best preserved in full containers, brown bottles or tins. Turpentine is almost a pure, refined chemical; it contains 92 to 96% of a compound known as pinene. Wood turpentine usually contains in addition, appreciable amounts of dipentene. Pine oil is largely terpineol.

These spontaneous reactions occur very slowly; when turpentine is used as a thinner for paints and varnishes it evaporates much too rapidly for any of them to take place; it is therefore just as inert, and has the same indifferent effect upon paint films, as its petroleum substitutes. These remarks apply only to the fresh product. Turpentine which has undergone changes by reason of long storage is easily recognized upon examination; if it has lost its pleasant odour and acquired a disagreeable sharpness, or has become viscous and gummy, it should be discarded. Containers in which turpentine has

undergone these changes should be well rinsed out or discarded; a small amount of gummy residue may affect a fresh supply or speed up its reactions.

Turpentine should be kept in full, tight containers away from light; but its preservation is seldom a matter of much concern, because of its low cost and availability, and because the average painter will consume his supply rapidly.

WATER

The role of water in the various processes of the artist is considerable, yet it is often overlooked. Water is probably the greatest or most universal solvent; hence it is easily subject to contamination. Pure water will dissolve and hold in minute quantities, substances which for all practical purposes we ordinarily consider insoluble. All natural waters from springs, wells, lakes, and rivers, such as are used for general water supply, contain varying amounts of salts which have been dissolved from the rocks and earths with which the water has come in contact. Everyone is aware of the fact that excellent drinking water is often unfit for certain uses; for instance, it cannot be used in storage batteries because of the salts it contains. Hard water—that is, water with a relatively large amount of calcium salts—cannot be used for laundry work or in steam boilers without first being treated chemically.

Writers on water-colour technique usually recommend distilled water, which is chemically pure, because the salts in ordinary water are liable to break up the fine dispersion of some colours, causing agglomeration of particles, or graininess; also because of the minute cloudy or whitish film which such salts may deposit on drying. Practical water-colour painters, however, usually disregard this precaution as an unnecessary overrefinement, unless the water supply happens to be unusually bad in this respect.

It is advisable to use distilled water in the preparation of tempera emulsions; small amounts of mineral salts have a bad effect on the formation and stability of emulsions and colloidal solutions. Rain water is free from mineral salts but not altogether reliable, as it has plenty of opportunity to pick up impurities, especially if it passes through polluted atmosphere.

Fresco painters generally are very careful to use nothing but distilled water, because experience shows a decided danger to the surface effect from the introduction of small amounts of impurities. Also, mineral salts are considered to interfere with the colloidal nature and hence the plasticity of the mortar.

Water may act as a destructive force on all sorts of paintings, either by coming into direct contact with the paint film from the front or rear, or in the form of atmospheric moisture. For this reason, new plaster walls must be allowed to become thoroughly dry before oil paint or adhesives are applied to them. According to the best practice, it is advisable to wait at least three months before the application of ordinary oil paint to new walls; for permanent artistic painting and permanent adhesion of mural canvases, one must be even more careful; as much time as two years has been recommended.

Plaster applied directly to exterior walls presents a very doubtful surface for permanent painting.

The destructive alkaline reaction of plaster walls upon paint coatings diminishes with the ageing of the plaster. In industrial practice, when circumstances make it impossible to allow sufficient time for this purpose, the walls are neutralized by applying a solution of zinc sulphate of about 20% concentration; but ageing is preferable. When a wall is completely dry, the alkaline action of the plaster has much less effect upon paint coatings; moisture is necessary to cause a reaction between the alkali and the paint. According to some experienced workers, 3% of moisture is the maximum allowance for correct procedure; according to others, 5% is permissible.

An old method of testing the moisture content of a wall is to affix a sheet of gelatin to the wall by its upper edge; the moisture in the wall (and in the atmosphere as well if it is not a dry day) will cause it to curl up; if this occurs within five minutes the wall is too damp. The modern method is to use specially constructed moisture meters; one of the most convenient and accurate of these instruments is the Sunvic Moisture Indicator,* which operates on the Wheatstone Bridge principle, or the measuring of the unknown resistance, in this case the resistance between the steel points of a probe. To test a plaster surface for moisture content the points of this test-probe are firmly pressed into the material and the meter to which the probe is attached indicates whether or not that area is dry enough for painting or adhesives. The apparatus is contained within a small box, some $5\frac{1}{2} \times 5\frac{1}{2} \times 7$ inches, and is operated by a battery contained therein.

Tempera Emulsions

As stated before on page 308, the published data on the theory and practical applications of emulsions are not very complete, and there have been no exhaustive studies of the subject from a tempera-painting view-point. Most of our opinions are based on observations of an empirical nature and adapted from theoretical and industrial researches; as a result, we are still somewhat in the dark as regards a complete control over the practical technology of emulsions as applied to artists' paints.

When a tempera emulsion dries, the oil globules seem to disperse into a homogeneous mass with the water-soluble and stabilizing ingredients, so that the film takes on the character of a clear solution of these ingredients in an oil film. Laurie[34] says that the oil content alone should be sufficient to bind the pigment; as noted previously on page 116, this amount is really quite small compared with the amounts we are accustomed to employ in paints in order to grind and apply the colours. He describes some experiments to determine how much oil, according to this theory, should be added to artificial emulsions. Equal amounts of pigments are ground with different amounts of oil (thinned with turpentine to make grinding possible), until the amount of oil which will produce an adequate bond is discovered. To this

* Sunvic Controls Ltd., 10 Essex Street, Strand, W.C.2

suggestion might be added the remark that a good starting point for such experiments could be obtained by grinding a measured amount of pigment to a very stiff paste with oil, then adding an equal amount of pigment ground with turpentine; for in the case of the average pigment, 50% of the volume of oil necessary to grind the paste is not far from the amount necessary to bind the colour.

The proportion of oil to pigment thus arrived at is then to be used as a starting point for experiments in adding various amounts of the aqueous ingredient. It must be understood that this whole method is a theoretical one, to be used as a basis for experiments rather than accepted as a regular procedure. In most cases it will be found that for the production of an emulsion which is of any practical value as a painting medium, the amount of water or water solution will have to be considerably greater than these theoretical figures indicate. Pure egg-yolk, which yields a satisfactory but none too hard film, contains only about $\frac{1}{4}$ or less egg oil by weight.

Composition of Hen's Eggs. The chemistry of egg ingredients is extremely complex. Almost all of the published researches on eggs have been done from the viewpoint of nutrition and not in relation to their technical uses. The following data have been adapted from various food sources. The percentages given are average and approximate.

Whole Egg

Water	73·0%
Water-soluble ingredients	14·5%
Oily ingredients	12·5%

Yolk

Water	49·0%
Water-soluble ingredients	17·5%
Oily ingredients	33·5%

White

Water	87·0%
Water-soluble ingredients	13·0%
Oily ingredients—a trace	

Typical Analysis of Hen's Eggs

Yolk

Water	49·5%
Fat	18·0%
Lecithin and allied substances	11·0%
Proteins	14·5%
Dextrose	0·3%
Cholesterol; lutein; other substances	5·7%
Ash	1·0%

White

Water	86·2%
Proteins	12·7%
Dextrose	0·5%
Ash	0·6%
Lecithin, cholesterol, egg oil—traces	

Egg oil is a non-drying oil which imparts desirable properties to the tempera film. It is carried along by the powerfully drying and adhesive proteins to produce a film which becomes dry.

The proteins in egg are complex; they are almost all of the type which coagulate upon being exposed to the light and air in thin films. They are usually grouped together and referred to as albumen.

Albumen is an efficient stabilizer of oil-in-water emulsions. The egg oil and the albumen are the principal ingredients of the egg tempera film; the other substances contribute minor properties.

Lecithin is a still more powerful stabilizer of oil-in-water emulsions than albumen, and tends to form permanent, finely dispersed emulsions in many natural animal and vegetable products. It is classed as a lipoid, lipoids being a group of natural organic substances which have many of the properties of fats. It occurs in egg oil together with other similar compounds of which it is the principal one (about 10% of the yolk).

Lecithin from vegetable sources (principally soya beans) and from egg, is produced commercially; also egg oil that has been expressed from hard-boiled eggs. These have been applied with little success in the production of paints, but are used to considerable extent in the tanning of leather and other industrial processes.

Cholesterol, another lipoid or fat-like substance, is an important constituent of many animal glandular products and is a recognized stabilizer of the opposite, or water-in-oil, type of emulsion. Lutein is a fugitive yellow colouring matter; chemically, it is almost identical with many vegetable yellows. Dextrose is a form of sugar commonly called grape sugar. The ash is the residue left after the egg has been ignited; it consists of inorganic or mineral salts of some variety.

In the study of emulsions it is recognized that cholesterol and lecithin have an 'antagonism'; lecithin absorbs water and acts as an oil-in-water stabilizer, while cholesterol tends to stabilize the water-in-oil type of emulsion. The presence of both of these materials might possibly have some bearing on the erratic action of egg-yolk/linseed oil emulsions mentioned under *Tempera Painting*.

Tempera emulsions or painting grounds which contain wax, egg-yolk, or (especially) casein, will invariably turn yellow if they are emulsified with ordinary linseed oil; they will turn less yellow with poppy oil, and least yellow with stand oil thinned with a little turpentine. Correct procedure thus seems to prohibit, in general, the use of these animal products with vegetable drying oils. The yellowing is usually attributed to the action of

water on the glycerides of the oil during the drying process, but it is quite likely that it is increased by the action of some substance which is common to most of these animal products, because other emulsions of linseed oil, such as gum tempera, do not turn yellow to such an extent, if at all. When linseed oil is emulsified with casein the yellowing is so pronounced that casein/linseed oil emulsions are forbidden by all careful investigators; when it is emulsified with egg, the yellowing is slight enough to be controlled and kept to an acceptable minimum; nevertheless it is present.

An emulsion is usually made by pouring one of the ingredients into the other in a thin stream while stirring the mixture vigorously. In general, they are best made when both phases are of rather heavy or viscous consistency. Some emulsions will not combine without the vigorous agitation of a mixing machine, and most of them will not remain in suspension or contain very finely divided droplets unless given a complete and thorough mixing. The most convenient apparatus for the manufacture of small quantities of emulsions is an electric mixer such as is sold for household use, and if it is of the type that can be held in the hand as well as placed in a stand or holder, its usefulness is increased. Care must be taken to keep both motor and stirring blades clean; the stirrer should be cleaned and dried after each using, and the motor oiled regularly. Do not allow the cord to come into contact with liquids. The shape and size of the container should be in proportion to the amount of liquid used. If the container is quart-size or smaller, from three to five minutes' mixing with one of these little machines will usually be sufficient. When small batches are wanted—four ounces or less—emulsions may be more conveniently made by shaking the oily and aqueous ingredients together in a tall bottle no more than three-quarters full. Oil-sample vials or the common 8-ounce or 4-ounce feeding bottles which are scaled in half-ounces are convenient. Emulsions may also be made by mulling the oily ingredient drop by drop into the aqueous ingredient on a slab. On a large industrial scale, all three of these principles are used, but usually an industrial emulsion is considered crude or incomplete until it has been put through a second very powerful machine which makes the emulsion more permanent by decreasing the size of the particles. An ordinary egg-beater and jar is a less convenient but often adequate substitute for the electric mixer.

When a wax is to be emulsified it is melted, and the water or aqueous solution, warmed to a temperature above the melting point of the wax, is added in a thin stream with constant agitation. If the solution is allowed to cool too much, the wax will solidify upon coming in contact with it, and the emulsion will not be formed. A solid which has a melting point higher than that of boiling water may be emulsified by melting it and thinning it to a liquid form with an oil or volatile solvent, if such a mixture is suitable for use in the formula. All of the waxes melt below the boiling point of water and can be melted in a water bath, but when they are mixed with resins, the mixture usually requires direct heat.

Some of the modern synthetic industrial emulsifiers may eventually

prove to be well suited for the preparation of painting emulsions of improved behaviour and stability.

Glues and Gelatin

Properties and uses of glues and gelatin are discussed under *Gesso* in the section on grounds and on pages 281–2. That the chemistry of these products is not well established and the control of their manufacture is largely empirical, will be gathered from the statements in those sections.

From the maker's viewpoint, gelatin is simply a pure form of glue, made from more delicate animal tissues and refined with greater care and cleanliness than is ordinary glue. Chemically, the complex proteins of which gelatin is composed can be grouped roughly into two classes, sometimes called chondrin and glutin; the former is responsible for its adhesive properties and the latter for its gelation. Glue contains more chondrin and less glutin than gelatin.

Technologically, the difference between glue and gelatin is considerable. The user of both of these products regards gelatin, not as a purified glue, but as a material of the same origin, with similar properties, especially when used as a size, but of different behaviour when used as an adhesive or binder. The difference in composition is one which involves colloidal as well as chemical properties, and the behaviour of each of these materials as an adhesive or as a constituent of a binder or film-forming medium, is different from the behaviour of the other. The best grade of bone glue is inferior to all but the very lowest grades of hide glue.

The highest-grade gelatin will make the strongest jelly, but its binding, adhesive, and finishing properties will not equal those of the high-grade skin glues. Rabbit-skin glue has the correct balance of properties for use in gesso. The calf-skin glues are so pure that they may be considered gelatins from the manufacturers' viewpoint; nevertheless, they have the adhesive strength of hide glues and are also balanced enough for use in gesso. Selection of a glue for technical purposes is usually based upon the correct balance of properties rather than upon one desirable property. A heavy viscosity in the liquid state is apparently considered an indication of a glue's adhesive strength, and is also a desirable quality for uses where too much penetration is not wanted, as in application to cloth when it is undesirable for the liquid to soak entirely through to the other side of the fabric. The jelly strength is a definite indication of a glue's value for sizing, gesso, and some other binding purposes.

Glue, gelatin, casein, albumen, egg-white and yolk, all belong to the same class of products of animal origin (proteins). One of the properties which members of this particular group happen to have in common, is the ability to form viscous colloidal solutions in water; and one of the reactions some of them display is a property of being coagulated or denatured when exposed to certain conditions, such as heat (as in hard-boiled eggs) or sunlight (as in drying of egg tempera). Glue dries and hardens to form adhesive or binding layers, but none of its original properties are changed, and sub-

sequent application of water will redissolve it. Casein forms similar dry films of adhesive or sizing qualities, but these films are not so completely soluble in water. The dried product resembles the original casein, which did not dissolve without ammonia; it is therefore very definitely more resistant to moisture than is glue. It is a mistake, however, to consider casein films or paints completely waterproof. Compared with those of glue, they are merely more resistant to disintegration by moisture—in many cases sufficiently resistant to suffice for certain purposes where glue would fail; but casein paint films and gesso may be picked up or disturbed by water to a considerable extent.

Glue and casein paint films, putties, gesso, and the like, may be enormously improved, to an extent that will render them more impervious to atmospheric moisture (and for all practical purposes to applied water or aqueous mediums if these are carefully handled and not scrubbed in), by the application of certain chemicals which have the property of toughening, hardening, or tanning them. Here again, the resulting surfaces are sometimes inaccurately called waterproof; their resistance to moisture is increased appreciably, but water, although it will not completely destroy them, can, if not carefully applied, damage them severely. The differences between glue and casein hold true in the tanned products: the chemically hardened casein is proportionately more moisture-resistant than the chemically hardened glue. In industrial use, solutions of the following materials may be added to the batch or sprayed on to the surface to harden glue and casein films: alum, chrome alum, sodium or potassium bichromate, and tannic acid. But although these chemicals are or have been used industrially, they are not to be recommended for materials for permanent painting, because their products will remain in the film; therefore more volatile substances are employed for artists' purposes. The best hardeners belong to a class of completely volatile materials of which formaldehyde is the most widely used example; the best hardener for casein, glue, or gelatin is a 4% solution of formaldehyde, which is brushed or sprayed directly on to the film. A 40% formaldehyde solution is universally obtainable in drug stores, usually under the name of formalin. Its highly penetrating, unendurable fumes are familiar to most people through its use as a fumigant; however, when it is diluted with nine parts of water to give the 4% solution, it can easily be handled, and there is no irritating effect on the eyes and throat.

Acetone also has a powerful coagulating or flocculating effect on casein and aqueous colloids in general, but it is not generally used in this connection; no controlled definite recipes for its application as a hardener of such films are in circulation.

All of the above-mentioned materials can be added directly to glue or casein liquids so that they will harden to tough, water-resistant films, but the disadvantages of the films containing such active chemicals is obvious. The behaviour of glue and gelatin is tricky and erratic in this respect; such hardening materials must be added to them just prior to use, and must be very delicately controlled; there is less difficulty in the case of casein; the

commercially prepared adhesives described on page 279 contain many such materials, and the industrial flat casein wall paints sold in paste or powder form usually contain lime, which not only assists in their solution but has the property of increasing their resistance to washing. For permanent artists' materials, spraying with the formaldehyde solution is the most approved method of hardening or tanning casein or glue films. A recipe for the addition of formaldehyde to a casein solution is given on page 277. Great care must be observed during the mixing.

It is neither necessary nor desirable to heat glue or casein over 160° F.; heating to the boiling point is definitely destructive and spoils the product for use in any exact formulas.

The addition of small amounts of alum (about 5%) to hide glue or gelatin in order to harden it and render it less hygroscopic for use as a sizing for paper and for other uses requiring weak concentrations, is a procedure which has been employed effectively since early times. It is not used with bone glues; when alum is added to a solution of bone glue the solution becomes muddy or turbid. This reaction can be utilized as a test to distinguish hide from bone glues.

Plaster of Paris and Gypsum

When native calcium sulphate (gypsum, $CaSO_4.2H_2O$) is roasted at 212–374° F., it loses three-fourths of its water of crystallization and becomes $CaSO_4.\frac{1}{2}H_2O$, the familiar plaster of Paris. When mixed with water to a plastic consistency or a heavy cream, it takes up the one and a half parts of water again, and when dried, hardens to a uniform solid mass which is inert and no longer reacts with water. If plaster of Paris is soaked in a large excess of water, enough so that it settles to the bottom of the vessel instead of forming a paste, it will take up the water and become inert in the form of fine particles without solidifying to a continuous mass. The material has enough hydraulic characteristics to set, at least partially, under water; therefore it must be stirred often during the first thirty minutes of slaking, and once every day until it is smooth and creamy, after which setting will not occur. Chemically, both the slaked and the hardened plaster of Paris are the same as the original gypsum, but they differ from it and from each other in crystalline structure.

Use in Gesso. As noted under *Gesso*, Cennini used slaked plaster of Paris as a pigment for gesso. The painters of his day and locality used it because it was the most brilliantly white, inert, and pure material of its type widely available; but when whiting in uniform, pure grades became an article of commerce, it replaced this material. The very fine Paris white was a further improvement, and precipitated chalk a still later one. In accounts of other countries and times, chalk is as frequently mentioned as gypsum or plaster of Paris for use in painting grounds.

A chemically precipitated calcium sulphate is also available; under the microscope, the particles of this variety show up as long, needle-shaped

crystals which have a tendency to mat or felt with each other. For this reason some writers of the past have recommended slaked plaster of Paris for producing a gesso of superior durability or elasticity. Finely powdered native gypsum and slaked plaster of Paris, however, do not have this monoclinic crystalline structure to any marked degree; moreover, it is extremely difficult to obtain any of these products in a pure state, free from lime or other alkaline impurities.

Pure plaster of Paris when mixed with an equal volume or about one-third its weight of water will set rapidly, becoming hard and solid in five to fifteen minutes. This is the reason why plaster of Paris is used for moulding; the speed of its setting is greater than that of the evaporation of water; hence there is no shrinkage. Most other plastic materials shrink upon setting. Plaster of Paris hardens best in a dry atmosphere. It sets because of its slight or partial solubility; the small amounts in solution crystallize out and interlock or cement with the insoluble particles in a way similar to that in which lime sets. The addition of as little as $\frac{1}{4}$ of 1% of hide glue will delay its setting for two hours. Slow-setting and medium-setting plasters are sold ready-mixed with retarding ingredients. Gypsum and plaster of Paris were used in the earliest primitive civilizations.

Keene cement is a thoroughly burnt gypsum from which all the water of crystallization has been driven, and it contains additions of alum or other salts. It dries to a very hard mass and is used as a patching plaster for walls and in places where the surface may be subject to much wear.

Soap and Saponification

Soap is made by boiling an oil, fat, resin, or wax with an alkali. The water-soluble soaps used for washing purposes are made chiefly from vegetable oils and animal fats. A carefully made neutral soap, such as cake shaving soap, Ivory, Lux, etc., contains no alkali; however, when it is mixed or dissolved in water, a minute amount of alkali is produced by a chemical reaction (hydrolysis)—sufficient in many instances to alter the surface colour effect of a painting. The principal action underlying the functioning of soap as a detergent or cleanser is generally supposed to be a colloidal one; the various theories which have been advanced are based on various interpretations of the chemical nature of dirt. The particles of dirt are usually considered to be more strongly attracted by the soap solution than by the substance which they stain.

The removal of varnish from paint with soapy water is clearly, from observation, a process of solution, accompanied (or preceded) by some saponification, which is probably the most essential part of the action. Disadvantages of the use of soap for this purpose, other than those enumerated in the discussion of the cleaning of oil paintings, are: (1) colour particles are drawn into the soap solution from an otherwise seemingly unaffected film, (2) soapy water seeping into cracks does far more harm than plain water, and (3) the presence of dirty suds hinders visual control of the progress of the work.

Some dirt films are attached by superficial adhesion, some by adsorption; those of an oily nature can be removed by aqueous solutions only when they are emulsified by soap, or saponified (made into a soap) by free alkali. Free alkali will attack and sometimes destroy adsorbed layers.

The so-called metallic soaps, whose manufacture also involves the saponification of oily materials but which are insoluble in water, are described on page 148.

LITHOGRAPHY

From the period of the development of the lithographic process down to recent times, the chemical principles underlying the various attractions and repulsions peculiar to lithography were not entirely explained in a way satisfactory to workers on the subject. The usual explanation that the free fatty acids combined immediately and directly with the stone to form calcium oleates, etc., and that the natural acid of the gum formed arabinates, was not convincing to those who were familiar with the feebly reactive nature of the acids of oil and gum. The improbability of the occurrence of such reactions with infallible precision under the variable conditions present in lithographic practice, was noted, but until recently was not proved.*

The conditions set up in the stone are not caused by superficial coatings of oelates, arabinates, and other products of reactions which could be dissolved with solvents, but are permanent effects in the stone itself which are produced chemically and can be removed only by mechanical means, that is, by grinding the layer completely off the stone.

The action, according to modern investigators, is adsorption, a reaction referred to in the first part of this section. Many substances, particularly when their surfaces have been recently and carefully cleansed, have the property of adsorbing layers of acidified gum arabic and lithographic crayon to produce conditions under which lithography is possible. According to this theory, an adsorbed layer of fatty acids is formed under the crayon marks, and non-polar deposits incapable of adsorbing fatty acids are set up on the rest of the stone by the acidified gum arabic of the etch. These layers are so thin as to be immensurable; it has even been suggested that they are monomolecular, because of certain theories of adsorption.

The animal and vegetable oils, fats, and waxes of the lithographic crayon contain fatty acid molecules, which are capable of forming orientated layers, as previously described in this section under *Adsorption*. If pure mineral oil, which has a different molecular arrangement, is applied to a sensitive stone, it will not set up a lithographic printing condition; if minute amounts of fatty acid are added to it, a very slight smudging effect will be produced, because the material then contains some traces of orientated acid molecules. These facts contribute toward the proof of the present theory.

The reason why lithographers have found it wise to allow the etch or

* Tritton, F. J., 'A study of the theory of lithographic printing.' *Journal of the Society of Chemical Industry*, Vol. 51, pp. 299–306, 307–313. London, 1932.

gum solution to dry before washing it off is that a very concentrated solution of gum is required, and this is most easily obtained by allowing the solution to dry down on the stone.

The operation known as rolling up is important, because it speeds up and completes the process of adsorption by means of mechanical pressure, an established way of accomplishing this.

ETCHING

Preceding remarks on the nature of acids will throw some light on the reason for accurate formulation of etching mordants, both as regards choice of acids and concentration.

In the first place, a certain optimum dilution with water is required to secure the proper dissociation or ionization of an acid so that it may act most efficiently on a metal. An extremely violent action is not desirable, because it would be uncontrollable and probably erratically uneven, and also because the force of the bubbles of a violent ebullition and the heat generated thereby would have a mechanically destructive effect on the fragile coating of resist, particularly where there are delicate lines.

Sometimes when a metal is immersed in a full-strength acid—for example, zinc in concentrated sulphuric acid—the metal becomes almost immediately coated with the end product (zinc sulphate), which effectively protects it from further action by the acid; if the acid were diluted with water, this salt would go into solution as soon as it was formed, and the metal would remain clean and exposed to the action of the acid as long as desired.

On the other hand, a too dilute solution is also impracticable; the length of time a plate would have to remain immersed or in contact with the acid would eventually cause the ground or resist to be affected; the etcher also wants a certain amount of continuous bubbling to occur so he may know how the reaction is proceeding and thereby be in control of it. False biting through the failure of the resist in spots can be immediately observed by the bubbling, and steps can be taken to stop it by rinsing the plate, drying it, and giving these places an additional touch of acid-proof varnish or resist.

Copper is much less reactive chemically than zinc; comparatively, it can be classed among the inert or durable metals.

11

Conservation of Pictures

This chapter is not designed to be a complete manual of instruction; should some of the data seem to be presented in too great detail in proportion to their importance, it may be explained that this is done because these facts, some of which are common knowledge to experienced restorers, have hitherto remained unpublished, or because published accounts of them are vague, contradictory, or not readily available.

The modern tendency is to refer to this subject as the conservation of works of art; this term includes all measures taken and studies made for the purpose of rehabilitating damaged or deteriorated works and preserving or maintaining works of art under correct conditions. Restoring refers only to the replacement of missing portions, imitating the original by the use of paint or building up missing fragments of sculpture. The distinction is a proper one, but it still seems convenient for the general art public to refer to the entire subject in ordinary conversation as restoring and to call its practitioners restorers.

Proficiency in restoration is not entirely a matter of fundamental artistic and chemical knowledge, materials, methods, etc.; these are necessary equipment, but their successful application is a result of expert skill and a sense of judgment developed by experience. Apart from understanding the strictly technical aspects of the craft, the worker must have an adequate comprehension of the artistic nature of the work upon which he is engaged. Toch[102] mentions preliminary experience and studies on the subject, and recommends continued study and experiment upon old and worthless pictures in various stages of decay. Perhaps the paramount consideration is the restorer's attitude toward the work; the pictures entrusted to him should be treated in a conscientious manner to the best of his ability, uninfluenced by other considerations. A well-qualified restorer may sometimes resort to unsound procedures, not through ignorance, but because of various circumstances.

In connection with this type of work, inexperienced persons means persons who have not completely restored hundreds of old paintings and so become thoroughly familiar with the emergencies that suddenly arise, with the little differences between one painting and another which may indicate totally different methods, or with the dozens of variations of cause and effect for which there are no written directions. The term inexperienced also includes the professional painter with a successful restoration or two to his credit. An experienced restorer is continually learning.

It is expected that the information in this section will be utilized by the amateur; the foregoing remarks are intended to impress upon him the necessity of knowing how much he dare attempt, and under what circumstances the work may be within or outside his capabilities.

General Rules. Most of the rules and instructions for restoring have exceptions, modifications, and limitations; these should be more or less obvious to the intelligent operator.

In attempting restorations, try to avoid doing anything that cannot be undone; keep it possible to return the picture to its *status quo* if necessary.

Do not treat a dilapidated canvas which is to be restored as though further rough handling will not matter. The difference between an ordinary restoration problem and a complicated or hopeless case is often slight. Also, every new blemish means just so much more work. The most troublesome operations the professional restorer is required to employ are often those made necessary by previous unskilful attempts at restoration.

Attempt should be made to save every vestige of original paint; repainting should be done only where all original paint is missing, as in the case of holes, burns, etc.

Too little perfection is preferable to overdone restoration. Work must be planned in advance in this respect, and judgment exercised in its execution.

Excellent restoration has been practised for a good many years. Generally speaking, the old, well-tried methods are superior to the more recent ones, but a considerable number of the modern materials and recipes are superior to the old.

As mentioned in the section on painting in oil, linseed oil is not a particularly good adhesive or glue. Therefore remember that a powerful glue is not necessary to make paint adhere to canvas; what is more important is stability—the power of the binding material to 'stay put' or remain unchanged under normal conditions. In the same connection, it should be borne in mind that conditions only slightly away from normal tend to destroy this adhesion.

One of the most powerful enemies of oil paintings is water, including water vapour or moisture in the air. Canvas is commonly sized with glue before an oil ground is applied. The picture consequently is separated from the cloth by an exceedingly thin layer of glue; if this be moistened from the back, the picture may immediately detach itself from the canvas. Water seeps through cracks and fissures when applied on the face of a painting and may produce the same effect. It is inadvisable to use water or mixtures containing water for cleaning most old pictures, and when the experienced restorer finds it necessary to do so, he will use it as sparingly as possible and dry the picture thoroughly immediately afterward.

Proprietary nostrums for the cleaning and 'regeneration' of paintings, whose composition is never published, bear the same relation to correct restoration as patent cure-alls do to the practice of medicine, and should be strictly avoided.

Repainting. From the very beginning of restoring, so far as can be learned from old writings, correct attitude and taste, and propriety of results, have been matters of great concern to those interested in the conservation of art; some of the earlier writers are surprisingly in agreement with much modern thought on the subject.

The use of restoration, in the narrower sense of the word as previously defined, must be strictly limited to the replacement of missing parts, and none of the original paint should be concealed. Various writers have proposed different approaches to repainting; in the case of a valuable artistic work, it is generally desirable to recondition the picture so that repairs are not readily apparent but so that upon close examination all the restored spots may be detected without trouble. Some of the suggested methods of accomplishing this are to use an entirely different technique of brush stroking from that used in the surrounding paint (hatching, stippling, etc.), to model fillings or plugs so they lie slightly below the surface, to paint them carefully but in colours a shade or two away from the surrounding areas, or to leave them vague or blank, tinted to match approximately the surrounding paint.

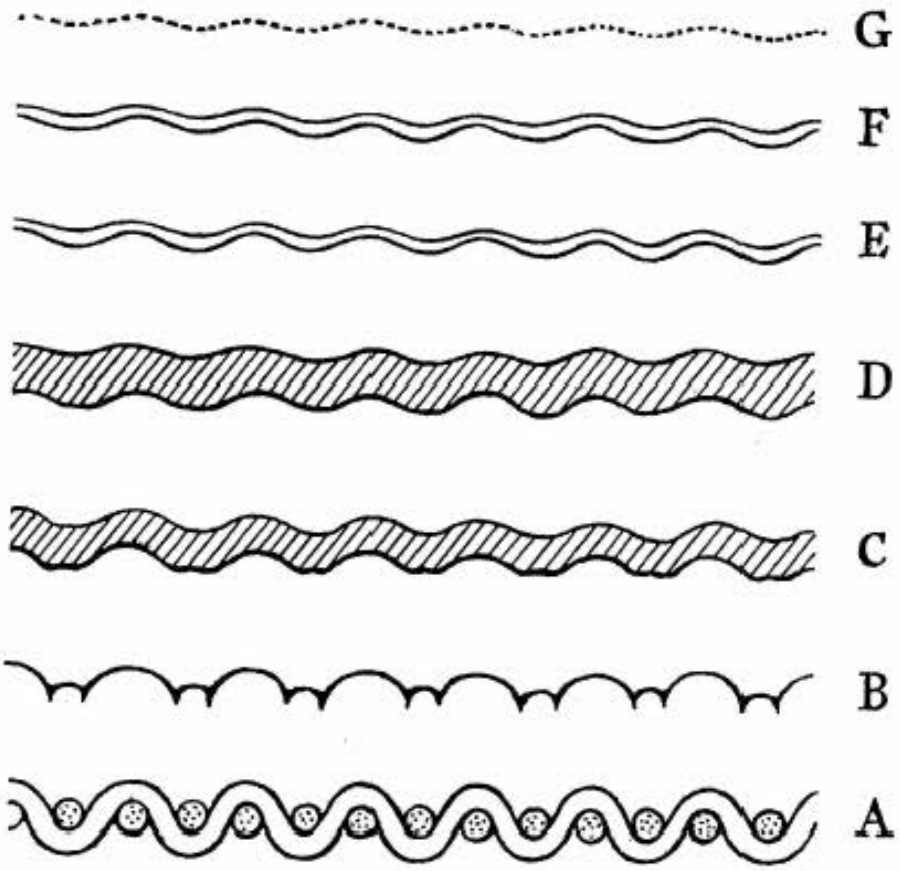
In the case of a semi-valuable painting regarded by its owner primarily as a wall decoration or of a portrait which is valued for reasons other than its artistic or historical value, the restorer is usually called upon to duplicate its original condition without blemish. In the instance of a modern work which has become damaged, particularly when the original artist repairs it or supervises its repairs, the same flawless perfection is required. Flatly painted areas such as plain backgrounds, or small lacunae in areas of single, flat tones, which bear no particular relation to individual draughtsmanship, are completely restored in almost all cases.

In writing descriptions of specific restoring processes, it is usually necessary to proceed on the assumption that a complete, flawless result is desired, and to leave the distinction between restoration and original work to the judgment of the restorer, whose decisions will usually be dictated by the conditions and auspices under which he works.

Relining

When injuries or decay in a painting on canvas have occurred to such an extent that patching, retouching, or other simple treatments will not rectify the defects or check the future disintegration of the picture and preserve it indefinitely, the painting must be relined.

This procedure consists in mounting the entire picture, including the old canvas, upon a new support, usually a new linen canvas. Logically the process should be called lining, but it is universally referred to as relining, a term which refers specifically to the conservation of decrepit paintings by this means. Canvases may be mounted on wooden panels for further rigidity, but this is usually considered an inappropriate alteration of the original work; furthermore, many old restorations of this kind have developed blisters,



ANATOMY OF AN OIL PAINTING

(Reading up from the bottom of the diagram)

A—Linen support.
B—Glue sizing.
C—First coating of ground.
D—Second coating of ground.
E—The painting. This may be one simple, directly applied paint-film, or it may consist of several layers, e.g.,
1. Underpainting
2. Overpainting
3. Glazes or scumblings
4. Isolating varnishes or veils.

F—Picture varnish.
G—Dirt.

warping, and cracking, defects which would not have occurred if canvas had been used; also, eventual further restorations are made more difficult. Except under unusual, special conditions, canvas is preferred. When additional rigidity is desired for any special reason, a well-braced Presdwood panel is better than wood—at any rate, in this climate.

Relining methods may be classified into two groups, according to the type of adhesive used: aqueous or non-aqueous. The former is the traditional and still the customary method; the latter is preferred by modern, scientific workers. The choice of materials should be determined by the nature of the defects, the degree of correction required, and other circumstances, but the

non-aqueous adhesives are to be favoured whenever they can be successfully applied.

The usual procedure, based on traditional methods, is to stretch the new linen on a temporary stretcher, eight or ten inches longer each way than the original, and give it a good sizing with a weak solution of hide glue or gelatin. The linen should be strong and of the best quality. As with linen that is prepared for artists' canvases, its weight should be sufficient to withstand all the strains to which it will normally be subjected, and a flat, square weave with identical threads in the warp and woof is most desirable.

For small pictures, up to 24 inches or thereabouts, the ordinary stretcher bars will serve for the temporary frame, but because longer stretcher frames will warp and twist in an annoying manner, careful workers use heavier wood for larger canvases, 2 × 2 or 2 × 4, joined with iron angles. The outline of the picture area may be ruled on both sides of this canvas with a pencil.

If the paint film is decrepit and likely to part from its canvas, paper is pasted over its surface, as described under *Transferring*. Some restorers recommend this in all cases, others only when they deem it necessary, but it is always safer to do it, especially when using an aqueous adhesive. The picture is then carefully and neatly cut from its original stretcher; sometimes the tacks are first removed with a screwdriver and the margin trimmed off with scissors or a sharp blade. When the picture is to be replaced in its old frame (and so far as circumstances permit, in every case), care must be taken not to diminish its size. A painting which is dilapidated around the edges is often trimmed to a smaller size by the restorer when with a little extra care and time he could preserve its full original size.

The back of the picture is gone over with sandpaper if necessary, to remove all knots and irregularities, and then scrubbed with a whisk broom. Previous to this, all significant inscriptions or stencilled marks should be photographed or carefully traced and preserved. Hot glue is than applied to the front of the new canvas within the pencilled outline; after it has set sufficiently, second and third coats may be applied, according to the restorer's judgment and experience. The glue should be applied with a wide flat varnish or enamel brush, and great care should be taken to keep the layer smooth and uniform. A typical mixture is French rabbit-skin glue, heavy wallpaper paste, and Venice turpentine. Three ounces of the paste are dissolved, free from lumps, in 10 to 12 fluid ounces of water and mixed with 6 fluid ounces of glue which has been soaked overnight in cold water, drained, and melted. An ounce or two of Venice turpentine is then emulsified into the hot glue-paste mixture with an electric mixer. Glue without paste will shrink too much and will not give a structurally durable film. The Venice turpentine imparts a little flexibility; also, without it the glue will not have the desired adhesive tackiness or penetration. Many other aqueous adhesives, including the casein-latex cement, have been recommended for relining. Glue and paste mixtures should contain a little preservative (see page 283) in order to prevent the formation of mould, should the painting be stored under conditions which would encourage its growth.

The back of the old painting is then given at least a thin coating of the hot glue and placed on the glue-covered area of the new linen. The canvases are pressed together with a rubber roller, or by rubbing with the palm of the hand, care being taken not to exert enough pressure to disturb the uniformity of the glue layer. Blisters or air bubbles are avoided by rubbing from the centre outward. Pieces of plywood, Presdwood, or other boards of the correct size (larger than the picture but smaller than the inside dimensions of the temporary stretcher) are useful for building up a support under the temporary stretcher so that this and other operations on the surface of the picture can be done against a solid backing. The picture is then set aside until it is nearly but not quite dry, after which it is ironed on the back with the heaviest sort of tailors' iron (about 20 pounds is a desirable weight; a lighter iron is less useful). A continuous gliding motion should be used rather than a pronounced stroking. The purpose of this ironing is to force the adhesive through the old canvas to the back of the ground, and also to cause a smooth, level condition. If the iron is too hot, it will cause the glue to liquefy to a greater extent than is necessary and to flow unequally. If the iron is too cool, the glue will not liquefy sufficiently to penetrate into the old picture and strengthen the adhesion of the ground to the canvas. Very hot irons will sometimes burn the paint.

For this operation the picture must lie face down on a perfectly smooth, hard surface; Presdwood free from blemishes is a good base. If the picture has any sort of impasto or sharpness of brush stroke, the points must be preserved by interposing a piece of blanket material, a pile fabric such as thin velvet, or other fairly thick, soft cloth between the table surface and the face of the picture. A small spot or point of paint raised any considerable distance above the level of the picture will be flattened out by pressure against an unyielding surface; this might not be so very harmful, were it not for the fact that the point is then likely to be surrounded by a small crater or concavity which will emphasize its crushed condition. Ironing the face of the picture is generally to be avoided; the experienced worker will know when it is necessary; and whether he irons it directly or protects it with a piece of cloth, he will take great care that the iron is not hot enough to burn the paint. Beeswax or paraffin may be spread over the surface to allow the proper slip and protection. When the picture is perfectly flat, it is ready to be cleaned. If paper has been pasted upon it, it is rippled off after sponging it with warm water. This water must not be allowed to soak into the picture, but it must wet the paper thoroughly; some skill must be exercised. The Presdwood or plywood panels mentioned earlier are useful as a support in such an operation. A painting will often require an additional ironing after removal of the paper.

Some writers recommend that ironing and other operations be carried out after the picture is on its final stretcher; this is a more cumbersome procedure; it requires the use of handled implements, made of thin wood or sheet metal and resembling trowels or mortarboards, for working on the parts of the canvas which lie over the stretcher.

Pressure in Relining

In the published accounts of restoring techniques, little or no mention is made of the use of presses and clamps during relining, yet they have been used to a considerable extent by professional restorers. A study of all the literature on the subject of restoring tends to give one the impression that their use is not in accordance with approved practice or that it is unnecessary. Yet old paintings which underwent relining seventy-five years ago or more, and which are in perfect condition, often show unmistakable evidence of pressure. All scientific and technical accounts of other adhesive procedures assume that pressure during the hardening of glues is essential.

By far the greater number of old paintings which require reconditioning present complications of more than one defect, usually rendering the literal application of published instructions impossible, as these instructions almost always assume that the defect under discussion is present in an otherwise intact picture. This is particularly true in the case of those pictures which have as an additional defect an irregularity of surface that requires flattening.

Very often an old painting on canvas has an all-over crackle which creates a sort of swollen, rounded effect, each unbroken area seeming like a raised island in the network of cracks; sometimes these areas are concave or sunken. Such irregularities of surface are caused by the unequal tension put on the fabric by the unbroken areas of paint and glue size, and the network of cracks where the film is discontinuous. It is often impossible to spread a coat of relining cement to a sufficiently uniform thickness so that the particular canvas being treated will be perfectly flat; in some cases the adhesive's slight variations in thickness, or unequal tension, will be transferred to the surface in the form of bumps or other irregularities. Often such conditions cannot be corrected by repeated ironing, but they may be minimized and usually entirely corrected by a skilful application of pressure.

The piling of weights on the average painting is usually ineffective; an enormous weight is necessary to equal the pressure of the most indifferently powerful press or clamp. The work of professional restorers will naturally be greatly facilitated by a properly designed press of a size large enough to accommodate most pictures; it may be specially constructed, adapted from machinery intended for other purposes, or improvised according to the ideas and resources of the restorer, and may operate on a number of fairly obvious principles. Good results, however, may be had by using large-sized carpenters' or cabinet makers' clamps, the advantage of a press over these being principally one of convenience. The all-metal clamps are more desirable than the wooden ones.

Pictures may be pressed between plywood panels of convenient size; the five-ply $\frac{13}{16}$-inch panels described under *Wooden Panels* are good for this purpose; another satisfactory material is a plywood of approximately the same thickness but made of five plies of maple of equal thickness in place of the thick softwood core and the four thin plies of hardwood veneer of which the other panels are constructed. This wood is not used in ordinary decorative

or structural woodwork, but is made expressly for mechanical and technical purposes such as the present one, and is less likely to warp and more likely to stand up under hard wear than the other. Pressure may be distributed by an arrangement of wooden strips or bars; 2 × 2 or 2 × 4 lumber, if it is not too badly warped, will serve the purpose.

An adequate supply of Presdwood is also very convenient; when it is used together with the heavier panels its smooth side may be placed against the picture; it is also useful as a smooth flat surface for ironing upon, and in the manipulation and handling of canvases generally. As mentioned before, when a canvas is mounted on a temporary stretcher, it is often convenient to have a panel or several sheets of Presdwood cut to a size around which the stretcher will fit so that work of various kinds may be done on the face of the picture while it is resting flat on a solid surface.

With canvases in a press, the same precautions must be taken as in ironing; if they have impasto or sharply pointed brush strokes, these must be protected as previously described so that they are not flattened out. When an aqueous adhesive has been used to reline a painting and ironing is not effective in producing a flat level condition, the canvas may be pressed after redampening the back of the new linen with a wet sponge. This procedure, of course, has all the disadvantages mentioned by those who oppose the use of water in relining, but in experienced hands it should not be dangerous. After the canvas and glue have absorbed a fair amount of moisture and have once more become uniformly damp and flexible, the canvas is placed under pressure for about forty-eight hours, preferably longer. Sheets of waxed paper should be used to prevent the moist canvas from sticking to the press boards, and strips of it may be placed along the borders of the face of the picture where the glue may have spread through the edges. Waxed paper may also be placed over the entire face of the painting when necessary, but the edges of the sheets are then liable to impress their marks on the picture. Waxed paper is useful in a number of other restoring manipulations but cannot be used against the face of a picture when heat is applied. It is not wise to wet the margin of the new canvas too much, as the glue around the edges thereby becomes too moist; the moistening should be confined as much as possible to the back of the picture area.

Upon removal from the press, the picture should be stretched without delay. Even if it seems perfectly dry, it usually retains sufficient moisture to cause buckling and inequalities if it is allowed to remain exposed to the air for long without being stretched. If the temporary stretcher is still attached, however, the canvas may be held taut enough to prevent this. Sometimes the procedure of dampening and ironing the canvas is repeated several times in order to flatten obstinately uneven pictures, because ironing or pressing will have little effect unless the picture is in a malleable condition. This moistening and steaming of the canvas is a good reason for preferring non-aqueous adhesives, as discussed under the next heading.

For various reasons it is sometimes desirable to reinforce a canvas by gluing a strip along a side or sides where the canvas goes over the stretcher,

instead of relining the whole picture. These strips may be glued on with strong relining glue, care being taken that their inner edges do not extend beyond the part of the picture concealed by the rebate of the frame. The strips should be wide enough for their outer edges to extend about 2 inches beyond the edge of the picture, so that they may be properly stretched. If raw linen is used, such strips should be impregnated with glue size before being glued on, and after they have been ironed or put through a press between strips of wood they should be painted with a good oil paint; their back sides may also be sprayed or brushed with formaldehyde if desired. The inner edges may be ravelled, as explained in connection with glued patches. Linen for this purpose should be strong but of a lighter weight or more open weave than the usual canvas type, and the glue should be applied evenly and not too heavily, or buckling may occur.

Non-Aqueous Adhesives for Relining

In several places throughout this book the harmful effects of water upon paintings have been noted. Water mixed into oil colours, especially when emulsified, produces weak, spongy films and favours rapid yellowing of the oil. Moisture in the atmosphere has its deleterious effects; water is generally taboo in cleaning old paintings on account of its effect on the entire structure of the picture.

For some years, many writers on the subject of relining and mounting oil paintings have declared that the water content of relining glues is likewise injurious, especially when the damp canvas is ironed: that the steam generated thereby is destructive, the entire painting weakened, and the cloth liable to shrink and cause loosening or flaking of paint or ground. Such writers are theorists more often than experienced restorers, but their opinions are not to be taken lightly on this score; it is quite likely that the moisture's penetration of the size which isolates the linen from the ground and of the ground itself if it contains glue or casein, may leave the painting in a weakened state. The alternative to an aqueous adhesive is a wax-resin mixture; such a mixture, however, has not been accepted to any great extent by professional restorers for reasons already outlined. Most old paintings suffer from a multiplicity of defects and the adhesive waxes do not meet the complete requirements in many cases, especially in regard to the appearance of the restoration; however, they do give good results when the picture is not too badly wrinkled, buckled, or otherwise irregular in surface. When a non-aqueous adhesive is developed which will give as satisfactory visual effects as the aqueous mixtures, it will no doubt be universally adopted because of its being less injurious to paintings. The attitude of the writers who favour the non-aqueous adhesives is that the painting should be conserved in the most permanent and harmless manner down to the last possible precaution, even at the expense of the completeness of the restoration; the attitude of the professional restorer who is guided by the preferences of the average patron, is that no process is correct and successful that does not put the picture in as

unblemished surface condition as possible. The latter point of view has accounted for much damage to valuable paintings in the past.

A typical formula for a non-aqueous adhesive is the following, taken from the publication mentioned under *Transferring:*

5 parts beeswax
3 parts rosin
1 part Venice turpentine

The harder and less brittle damar resin may be substituted for rosin if desired. The mixture may also be thinned with a very little turpentine for ease in application in certain uses; when this is done, it is assumed that the user will provide for the complete evaporation of the thinner during the progress of the work, either by ironing or by exposing the wax coating to the air for an hour or so before joining the two fabrics.

This is one of the few recipes given in this book which involve the direct heating of inflammable materials; the melting point is rather high for the mixture to be made conveniently in a water bath. However, if the can or vessel is not too full, and a metal plate is placed between it and the electric coil or gas flame, the fire risk is not great. If the mixture is to be thinned with turpentine, the light should be extinguished, and the can removed from the stove before stirring it in. The Venice turpentine is stirred in last, after the mixture has been removed from the stove.

Materials of this nature are applied to the back of the old canvas and to the prepared side of the new canvas (best quality prepared artists' oil canvas can be used instead of the plain linen employed in glue relining), which are then pressed together with warm (not hot) electric irons. Care must be taken to making the coating thick enough to provide a good bond, and thin enough so that it is possible to manipulate the iron without getting into trouble on the score of having the wax melt and run into unequal ridges and wrinkles. Care taken in applying a very even, uniform coating of wax with the brush or spatula will repay the worker in this respect.

When unprepared linen is used instead of oil-primed canvas, it is difficult to prevent the wax from running through it during ironing. The account mentioned on page 339 recommends the application of the wax to the old canvas, followed by a thorough ironing until, upon turning the picture over, the wax is observed to have come through the cracks of the old painting and to have soaked into the protecting paper. The new linen is then laid on and given just enough ironing to create a perfect and uniform bond between it and the softened adhesive wax.

The use of any appreciable amount of turpentine in wax adhesive is unwise; it will produce a salve effect like that of floor wax, with the result that the coating will be too tender, and the picture too susceptible to denting from minor contacts. For smoothing the wax on the mounted canvases, one may use electric irons of various weights, from the heaviest sort as used in glue relining, to those of smallest size, such as the rectangular irons and the tacking-iron sold for the mounting of photographs.

The purpose of ironing a wax-mounted canvas is to bring it to a smooth

level condition, and to impregnate as much of the entire structure as possible with wax. Sometimes obstinate spots may be flattened by a careful application of spot pressure, as described under *Patching*.

TRANSFERRING

Some conditions of structural decay cannot be rectified by relining, but by their nature require the removal of the paint film from its old support and the remounting of it upon an entirely new support; the most approved procedure is to use the same type of support as that originally used, unless some complex condition requires a change. In reconditioning a very decayed painting, the restorer must determine for himself whether transferring is required, or whether relining will suffice.

The removal of the paint film from the ground, or of the paint film together with the ground from the support, is a delicate and painstaking operation; yet it is not always so desperate or dangerous a measure as is popularly supposed. All conservation processes, even the most simple, demand of the operator the same skill and expert care; transferring differs from the others only in requiring a greater amount of time and painstaking effort.

Among the paintings so handled in the past are many well-known early Italian works which were transferred from panels to canvases in the eighteenth century after being brought to Paris.

The first procedure is to paste a sheet of plain newsprint paper over the surface exactly as in the relining of decrepit or flaking oil paintings. Strong flour or starch paste is used; it may be brushed on the picture as well as over the paper; should the paper become accidentally torn to a minor extent during application, it may be patched with a bit of paste-soaked paper; after the patch is dry a light sandpapering will remove the bump. Irregularities such as wrinkles (which a skilful operator will avoid) and overlapping of sheets may likewise be made smooth by a few rubs with fine sandpaper, after the paste has become thoroughly dry. Other materials have been recommended by various writers: layer on layer of tissue paper until a sort of cardboard has been built up; muslin or mosquito netting as either a first, intermediate, or last layer, with tissue paper; cartridge paper; and laminated cardboard. Some special papers are used by professional restorers. The main requirements for a paper for this purpose are that it should be of such a nature that it will serve as an adequate bond and protection for the paint film and not present too much resistance to removal at the end of the process. The newsprint paper referred to should be of ordinary quality; it is widely available in 50-pound rolls about 40 inches wide.

After the paste has dried thoroughly and completely, the canvas is cut from the frame; if it were cut from the frame before pasting, it would buckle and curl up during the drying of the paste. There is even some likelihood of this occurring after the drying, and the careful restorer will guard against this. He may handle a small picture as it is cut from the frame, or he may reinforce it by stiffening the edges; if the paper was made ¼ inch or more

larger than the painting all the way around, strong kraft or gummed paper strips may be pasted to this margin and folded under to make a sort of marginal frame. The picture may also be held flat, face down on the table or drawing board, by the use of gummed strips on this margin, or by weights.

However, the most convenient and safe method of handling the picture is the following, which is based on an account by Dr. F. Schmidt-Degener of the Ryksmuseum, Amsterdam.* The procedure described in the original account is the removal of an old glue relining and its replacement with a new piece of linen attached by the wax-resin mixture referred to under *Relining*, but the method outlined is also well adapted to the entire removal of the old canvas. The picture is first cut from its stretcher and four strips of heavy kraft paper about 10 inches wide or more, depending upon the size of the picture, are pasted along each of its edges not more than an inch in, on the face of the canvas. These strips are then pasted securely to a flat wooden frame made large enough so that there is a margin of 7 or 8 inches all around, between the canvas and the frame. The strips are then soaked with water and allowed to dry overnight, after which, if the work has been properly done, the paper will have stretched tight and the old canvas will be held in a taut, flat condition. (I have also used a single large sheet of kraft paper with the picture shape cut out of its centre and squares cut out of its corners where it folds over the corners of the frame.) The face of the painting is then protected by pasting over it squares of tissue paper overlapping each other by more than $\frac{1}{4}$ inch. (A single sheet of newsprint paper may also be used successfully.) When the paper has dried, the picture, thus mounted, is laid face down on a table and held rigid by iron weights on the corners of the frame.

The removal of the old canvas is accomplished by dampening it with a sponge, whereupon the linen, which is usually isolated from the ground by a layer of glue size, will become detached and may be carefully peeled up. The safe removal of the linen calls for patience and skill gained by experience; in many cases knives, abrasives, sponges, etc., must be used. After the canvas has been removed, exposing the back side of the ground, all traces of the old sizing must be scraped away from the ground. In a case of the removal of an old relining, a relatively thick coating of old glue must be removed; the account referred to recommends that equal tension be maintained on the old canvas by dividing it into squares and removing the glue with damp sponges and rounded knives in alternate squares, so that when the work is half finished it will present a checkerboard effect. The moistening of old canvases without these precautions of stretching, pasting, and gradual, uniform application of the water, is most liable to lead to damages to the painting through the too sudden shrinkage of the linen.

The new linen is mounted on a temporary stretcher just small enough to fit within the wooden frame upon which the old picture is mounted, and cemented to the back of the old picture in the manner of the relining process. The type of adhesive in each case is to be chosen according to the requirements of the work and the experience of the worker. The last operations are

* The *Museums Journal*. Vol. 32, pp. 86–87. London, 1932.

the cutting away of the paper frame and the careful removal of the newsprint or tissue with warm water and sponges, an operation which is not so difficult as it is tedious. A number of sheets of plywood or Presdwood cut to the proper sizes will aid in pressing and other operations, as previously described.

Pictures are similarly removed from wood panels by pasting a rather heavy protective layer over the surface and reducing the thickness of the panel to the thinnest sort of film, which can then be scraped away from the ground. The thickness is reduced by planing or by the use of a machine saw which can be set so that its penetration is limited. The back of the picture is crisscrossed with saw cuts, which are made as deep as is deemed safe, and then the squares are knocked out with a chisel. Murals have been safely transferred from plaster and masonry walls by laboriously chipping away the support from behind with a chisel. Sometimes such a picture, with its pasted gauze and paper protection, is rolled directly on to a large cylinder as it is separated from the wall, and is carried to a studio for complete removal of the adherent wall fragments, and for relining and repairing.

Patching

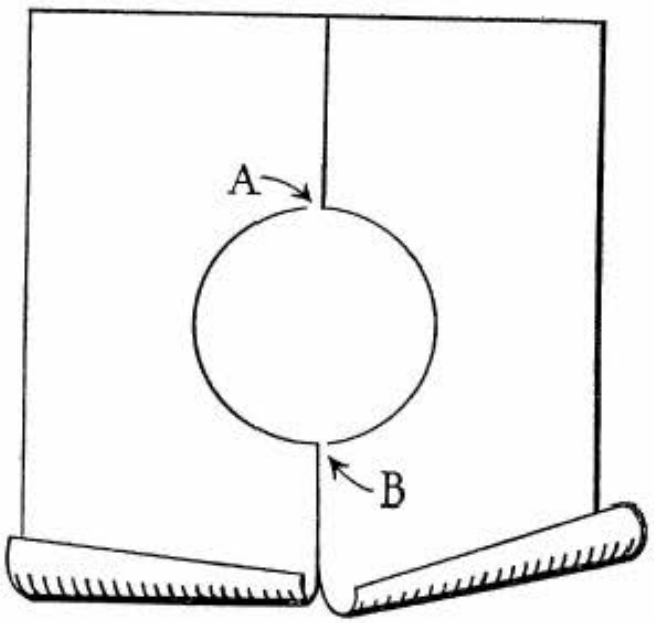
Small punctures and larger tears may be repaired by applying individual patches behind them, provided the painting is otherwise in good condition. The adhesive used is either of the wax-resin or of the aqueous glue type. The former is the easier to apply; it is less likely to make a mark on the face of the painting at the edges of the patch, and is more in accordance with the most approved modern practice. Also, it is more easily removed, if this should subsequently be necessary for any reason. The glue patches are more useful when the tear is accompanied by any considerable amount of wrinkling, buckling, or pulling of the threads, because the dampening of the canvas and subsequent application of pressure is more effective than the other procedure in correcting such defects; but when the buckling is not too pronounced the wax patches will also accomplish this purpose. Most patched spots will require filling in, as described on page 349.

The damaged canvas is laid flat and the edges of the tear fitted together; all overlapping threads or fibres, especially those which have a tendency to protrude upward, are trimmed with a sharp blade. A patch is cut from prepared oil canvas, and coated on the primed side with the wax-resin compound mentioned on page 337, placed behind the damage, and carefully pressed flat with a warm, not hot, iron. The heat and pressure should be just sufficient to create a flat level condition; too much will cause the wax to run in an irregular manner; too little will not allow it to penetrate and adhere permanently to the fabric. Some of the wax may appear around the outside of the patch; if it does, it should appear evenly all around; if desired, it can be neatly scraped or cut away after it hardens. The layer of wax should be fairly thick. A rubber roller may sometimes be found useful in making such patches flat.

Before the wax has become entirely hard, weights or slight clamp pressure may be applied to the patch in order to assure a flat level surface, if it seems necessary; not so much pressure should be used that the wax is forced out.

These operations are performed with the painting lying on a smooth table; for manipulations which require work on the face of the picture, the canvas should be supported from behind with several sheets of wallboard or a piece of wallboard resting on blocks, etc., as noted previously. The excess wax which fills the cavity should be carefully scraped out as thoroughly as possible, and the damaged spot or slit filled in and touched up with paint, as described farther on. This type of patch can be pulled off with the fingers quite easily; it is a good idea to make it round or oval, so that the danger of accidental pulling up of corners is minimized.

Sometimes when paintings have been patched with the wax adhesive, pressure applied to the face of the picture in handling it during the subsequent filling in, repainting, or other finishing operations, is sufficient to make the edges of the patch show through on the face of the picture; even the ironing may have this effect. To guard against this, I have used a method whereby the patch is incompletely cut out of a much larger piece of canvas, thus:



The patch is applied in the manner previously described and the entire square of canvas is allowed to remain until the job is completely finished, when the tiny connections A and B are cut with a keen blade and the surplus pieces pulled off. Bigger patches may have more than two of these points if desired. The square should be larger than the iron or at least large enough to bear careful pressure of the iron without its edges becoming imprinted on the face of the picture. The wax adhesive is applied to the patch and the corresponding area of the original canvas only; the ironing may cause some of it

to exude under the surplus canvas, but this does not prevent easy peeling off of the latter, and the excess wax may be neatly cleaned away later.

Pressure may be applied to patches of any kind by the following method: carefully round or bevel the edges of square pieces or strips of Presdwood so that these edges will not be impressed on the canvas; place one of the pieces on each side of the patched spot, and over each a piece of wood of somewhat smaller area (if aqueous glue has been used, slip a piece of waxed paper under each piece of Presdwood to prevent it from sticking); hold the arrangement in place with a screw or spring clamp. If the patch is far from the edge of the picture and only small clamps are available, an arrangement of wooden bars and blocks with clamps at either end can be improvised.

Aqueous Glue Patches. The big disadvantage of this method as compared with the preceding one which employs a wax adhesive is that the more powerfully adhesive glue will almost always pull or pucker the canvas around the patch, and make an irregularity which is clearly seen on the face of the picture.

Instead of prepared canvas, square or oblong pieces of plain linen are used, and a few strands are pulled out along each side. If the ravelled sides are kept as straight and smooth as possible, the effect is that of a bevelled edge which has less tendency to impress its design on the face of the picture than a sharply trimmed edge.

The linen is applied with hot glue of the type used in relining; the mixture may be thinned down somewhat with water, leaving it strong enough to supply permanent adhesion but not so strong that it has a puckering effect on the canvas. This is not a simple matter and requires some experience and judgment. Some writers recommend light-weight muslin or gauze for this purpose, but old pictures patched with these materials and glue often show the same kind of pucker or patch mark as is produced by linen and glue.

Woven or Mesh Patches. Nail punctures and similar small holes or slits may be patched by weaving a few strands of linen together, laying them over the back of the tear (Scotch tape will assist), and impregnating them with glue; when the glue has set partially, it is covered with a piece of waxed paper; rather mild pressure is applied with a clamp thirty-six hours or so, in the manner previously described. Fish glue, slightly thinned with water, seems to be satisfactory for such patches. They are inconspicuous in appearance and do not affect the face of the picture. Even on larger holes and tears, when there is not too great a space, I find that these patches, because of their open-mesh structure, hold plugs firmly and do not cause wrinkling. The wetting with glue and subsequent pressing will flatten puckered or wrinkled tears more successfully than will the wax-resin method. Too much pressure may produce an impression of the woven threads on the surface. Other more intricate methods, which include weaving in strands of linen, are practised by expert restorers; they call for considerable skill, patience, and ingenuity.

The wax-resin patches are the easiest ones for the non-professional restorer to use, as in the case when an artist must mend a tear in one of his own

works. Older methods of sticking on muslin or gauze patches with shellac, powdered resins, etc., have been more or less discarded, as they tend to give brittle, non-permanent, or blistery results.

Blisters and semi-detached pieces of paint may be glued down and pressed, if glue can be inserted under them. Such operations call for some practice and skill. A hypodermic syringe is often useful for inserting the glue behind blisters and other raised areas; in this case it is necessary to make a small hole by puncturing the film with a solid needle before inserting the hollow needle. It is sometimes recommended that these spots should first be softened with solvents, but this procedure is not always useful. The impregnation of a loosened surface by flooding it with gum, resin-varnishes, or oil, is likewise of doubtful value, except in some unusually complex cases.

Because of the difference in textural and colour effects between fresh repairs and old surfaces, all repairs such as patching, relining, and filling-in must be followed by cleaning and revarnishing operations whether or not the original surface condition of the picture was poor enough to have required such treatment had the structural defect not been present.

Cleaning Paintings

Removal of Old Varnish

The removal of old varnish by dissolving it and washing it away is not, according to universal opinion, to be carried to the point where the painting is denuded of every trace of its protective coating, because this is liable to result in the condition which the restorers call skinned. A painting so scoured presents the characteristic appearance of having had a minute amount of its surface peeled off; delicate tones, glazes, and lines are often partially or completely destroyed; points of white or pale-coloured ground or underpainting will show up in a sort of granular or stipple effect over large areas, and the entire colour effect may be altered so as to appear clouded. It is desirable, therefore, to proceed with the solvent under such control that a minute amount of the original varnish, made thoroughly uniform and dilute by the solvent, will be left. This can be done if the solvent is correctly applied; the surface will appear thoroughly clean, yet a very small trace of varnish will remain upon it. Among professional restorers, the operation of removing the varnish from a picture is called stripping.

The standard method of removing varnish from a painting by use of solvents is to apply the materials with small wads of absorbent cotton such as is sold in chemists'. This cotton is not only safe so far as abrading or tearing up delicate surfaces is concerned, but it also applies the solvent in a controlled manner and reabsorbs and holds in the greater amount of the dissolved material. Its whiteness and purity make possible a close observation and control of the amount of film being removed. The best grades, put out by the well-known makers of surgical dressings, have long fibres and are most satisfactory because they are free from the fuzzy lint of the cheaper

grades; but the cheaper grades sold in one-pound rolls under the name of hospital cotton are also adequate, and often seem to be more absorbent than the more expensive varieties.

In describing the usual method, we will assume that we have an average, well-painted portrait about a hundred years old, covered with a film of old varnish which has turned a dark brown colour and which is encrusted with accumulated dirt that seems to have become occluded into the film.

If the picture has been relined and is still on its temporary stretcher, it is laid upon the supporting boards mentioned on page 333; if it is on its permanent stretcher, cardboards must be stuck under the canvas and made rigid by being supported with blocks or boards of the proper height to fit between them and the table. This is to preclude undue flection of the canvas and to prevent the worker's bending the canvas over the inner edge of the stretcher, which would result in marks or cracks. Under no circumstances should pictures be cleaned with solvents in other than a horizontal position. The surface grime is first removed with balls of cotton which have been dipped into a non-aqueous liquid that has little or no solvent effect on the varnish, such as turpentine, mineral spirit, or solvent naphtha. The cotton should be well squeezed out so that it is just moist. This preliminary operation is not absolutely essential, but a heavy superficial coating of blackish dust often obscures the colour of the varnish and interferes with one's judgment of the progress of cleaning. Next, the solvent is selected according to the judgment and experience of the restorer, or after preliminary trials at the edge of the picture. Suppose a mixture of five parts of alcohol, three parts of turpentine, and one part of ethyl acetate is chosen: an ounce or two is poured into a suitable vessel and a wad of cotton is dipped into this and rather well squeezed out. The wad should then be compact and not more than about an inch and one-fourth in diameter, or small enough to be conveniently held and controlled between the thumb and two fingers. It is applied with a circular or back-and-forth motion, care being taken to keep the strokes small and to complete the removal of varnish to the desired extent before moving on to the next area. The rubbing face of the wad is continually examined for any traces of colour, and should the greenish, yellowish, or brownish colour of the removed varnish show any marked change, or should there be any other indications that traces of colour are beginning or about to be removed, the action is immediately halted by application of turpentine; an open container of turpentine and a well-soaked cotton wad are kept available for the purpose. The action may sometimes be more closely controlled by continual alternate applications of turpentine and cleaning solvent, one wad of cotton for each held in either hand.

When the face of the cotton has become saturated with varnish, it will neither distribute further solvent nor absorb more in the correct way, and it is turned around so as to present a fresh surface; one may usually use three sides of a wad, then tear it open and get one more useful surface from the interior. The used balls of cotton should be thrown into a container and disposed of as soon as the work is over.

When small spots of varnish of a greater thickness than the rest of the coating persist after the bulk of the surface is perfectly clean, or when such spots are found to be drops and spatters of a less soluble material, it is always dangerous to attempt their removal by continued scrubbing with the solvent, because the clean areas surrounding them are most likely to be skinned, every trace of varnish being removed. The paint film in those areas, if not actually picked up, will then be exposed to the danger of becoming weakened, softened, or altered in colour value by the continued action of the solvent. The removal of such spots is best accomplished with the knife, in the way in which fly-specks, spatters, and freckles are removed. (See page 348.)

The ideal volatile solvent or mixture of solvents will contain no water; if ordinary alcohol or a mixture which contains it be compared in practical use with a solvent which contains anhydrous alcohol, it will be found that in many instances the surface of an old oil painting will be bloomed or whitened by the solvent which contains a little moisture, and that it will not be so affected by the anhydrous solvent. It is possible that the water content of some alcohols will be great enough to produce all the undesirable and harmful effects which follow the application of water to an old, cracked oil painting. The anhydrous denatured alcohols described on pages 267 and 439 are miscible with turpentine. Anhydrous alcohol, ethyl acetate, turpentine, xylol (or toluol), and mixtures of these solvents are sufficient to carry on most picture cleaning manipulations; acetone and some of the other more powerful or special materials are useful in special cases. As mentioned under *Volatile Solvents*, the principles underlying solvent action and the behaviour of mixed solvents are rather complex; the properties of the different solvents are best learned by experiment. There does not seem to be any general rule or test for determining which solvent or concentration is best in any given instance; the worker must be guided by experience and by the results of careful preliminary trials.

Areas of paint composed of lead pigments which have become darkened by the action of sulphur-bearing fumes from a polluted atmosphere can usually be restored to their original colour by the application of hydrogen peroxide with a cotton wad. This reaction has been known since the early nineteenth century, when hydrogen peroxide was first obtainable.

Castor oil has been recommended for retarding and controlling the action of solvents, especially alcohol, on a painting; and according to Laurie[34] an undesirable absorption of alcohol by the paint film is thereby diminished. He recommends coating the picture with the oil and applying a mixture of alcohol and solvent into this with a soft brush, having more castor oil available to retard the action if it becomes necessary. He does not approve of the 'harsh and wholesale' absorbent cotton.

Castor oil serves another purpose in the removal of varnishes and repaints. One of the most successful paint-remover patents employs a waxy material dissolved in the volatile solvents. The wax not only holds the solvent in place so that it will not flow from vertical surfaces so easily, but it also keeps the solvent in contact with the paint or varnish for a longer time than

if the solvent's evaporation were unhampered. It is occasionally necessary to apply the strongest possible solvent action to an intractable painting; an addition of castor oil, 25% or less, will sometimes increase the solvent action of alcohol, apparently by holding it on the surface for a longer time. A wax salve made by thinning molten beeswax or paraffin with turpentine may also be used as a base for solvents.

If castor oil has been used in the cleaning of a painting, every vestige of its oiliness must be rinsed off with repeated applications of solvents, because it is an entirely non-drying substance, and paint or varnish applied over a trace of it may remain sticky for months. A disadvantage in its use on old paintings is the difficulty of removing it entirely from deep cracks and the canvas under the cracks; in my opinion, its use in general is rather unwise.

Soap and other powerfully detergent chemicals are ordinarily taboo in the cleaning of pictures. In the past, pure, neutral soaps have sometimes been recommended for perfectly intact, uncracked surfaces, but their use is never really safe, especially in the hands of an inexperienced worker.

The experienced restorer can often make good use of cleaning materials and methods which would be dangerous in unskilled hands, and there are, as has been previously noted, exceptions to the general rules and prohibitions, particularly in the case of such expert workers. The use of soap solutions by persons of limited experience is perhaps the cause of more injuries to old paintings than is any other procedure; although pictures may sometimes be cleaned successfully by this method, the number of old paintings which have suffered damage from it is quite large. The only alkali which has been given any sort of approval is ammonia, which is volatile and leaves no residue; its action, however, may sometimes be destructive so far as the life of the paint film is concerned, and it is not to be used except in very special cases and by experts. Laurie[34] quotes a recipe of Dutch origin for a cleaning agent made by treating copaiba balsam with ammonia, adding the latter drop by drop with continuous shaking until the mixture becomes clear and has a faintly ammoniacal odour. This combination is a powerful solvent, but its action may be controlled to some degree and is immediately arrested by an application of turpentine or kerosene. It works well, without apparent harm to old paint films. Saponin or powdered soaptree bark, which foams and duplicates part of the action of a soap solution without any of its dangers to the paint film, has also been recommended. Its value for delicate surfaces is well known and there are no objections to its use in cleaning pictures other than those which apply to water alone.

Pettenkoffer Method. Some cracked, dead-looking, or otherwise deteriorated varnish films may be 'regenerated' by exposing them to the action of alcohol vapours, which cause the surface film (especially when it is mastic varnish) to coalesce and appear as though it were in its original state. The process is named for its inventor, Pettenkoffer, and was in considerable favour during the nineteenth century, but because the varnish tends to revert to its former bad condition upon further ageing, and in some cases to

become even worse, the method has more or less fallen into disrepute. The fumes have a slightly similar effect when applied to a resinous or bituminous painting which contains wide traction fissures, but hardly enough to be of much practical value in the restoration of such pictures. Liberal application of copaiba balsam to the surface assists and improves the Pettenkoffer process. The procedure is best carried out by laying the picture face up in a shallow box made of sheet metal, to which a well-fitting lid is applied. The lid is lined with absorbent cotton held in place with wire screening, and the cotton is well soaked with alcohol, but not to such an extent that it will drip.

In practice, the process is ordinarily less desirable than the procedure it was designed to supplant, namely, the removal and replacement of old varnish. The action of fumes of alcohol and other volatile solvents can, however, be useful as an intermediate stage in some complex restoration processes.

Repaints. It is not always possible or desirable to preserve repainted areas or former restorations when cleaning an old painting with solvents; they are usually removed and, if necessary, replaced.

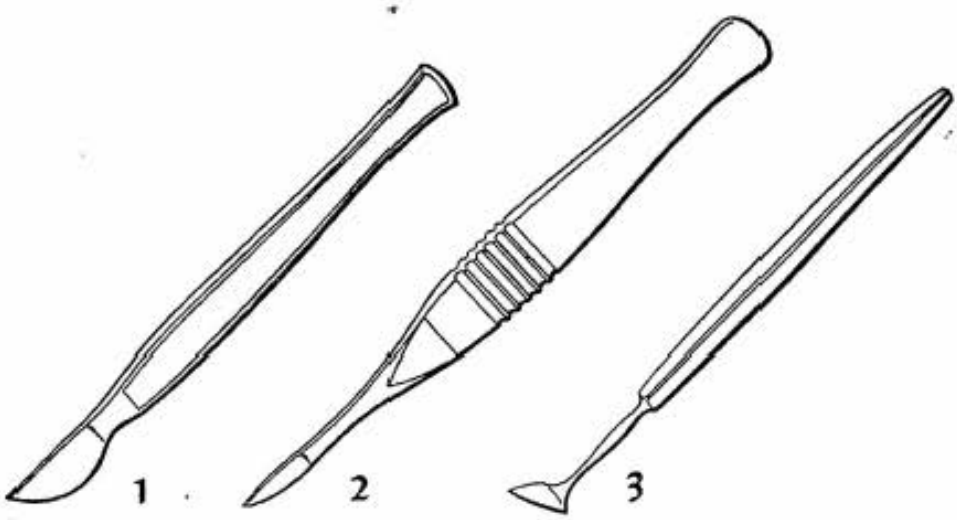
After the painting is cleaned, it is allowed to dry until it is free from tackiness; any necessary patches or fillings are made, and before these are repainted the entire picture is given the thinnest sort of coating of damar or retouch varnish that will produce a uniform gloss. The colours are thereby brought out in their final effect so that the repaints may be made accurately. When flat (mat) varnishes are used, they will occasionally seem to discolour the repaints unless these are first isolated with a very thin protective coat of glossy varnish. Some workers recommend coating all repaints with a thin isolating varnish which is insoluble in the solvent used in the finishing varnish; others condemn the use of any such intermediate varnishes, and bring out the tones for repainting by applying copaiba balsam considerably diluted with turpentine, a very thin layer of which is generally considered without harmful effect on the structure of the complete film. This subject is continued on page 351.

Cleaning Paintings without Solvents

The cleaning of paintings with solvents may be inadvisable or impractical in many instances, and methods are resorted to that may be classified as mechanical as distinguished from those using solvent action.

The older books on the subject describe an abrasion or attrition method for removing films of varnish (particularly mastic), which consists in crushing a bit of mastic, damar, or rosin, and rubbing it with a thumb or finger-tip (protected by a piece of gold-beaters' membrane) into the varnish film. The powdered mastic acts as a starter, the rubbing is done firmly and in small circles, and the varnish will continue to dust up and be removed. This procedure is practical only on works of the most level smoothness; the grooves and pits of brush strokes, canvas weaves, etc., will mostly remain untouched. The method is no longer widely used.

Use of Knives. In many cases the use of a knife or scalpel is the safest and best way to remove varnishes and overpaintings, especially from complex or delicate paintings. It is particularly effective when it is necessary to remove heavy repaints in oil or tempera from a delicate surface. The type of knife designated No. 1 in the accompanying drawing is best for general use in the removal of varnish; the blade, though small, is rather heavy. It is, however, necessary for complete practice to have an assortment of lighter blades for various contingencies, and instruments for special needs; these can be found among surgeons' instruments; they can be altered or ground down to serve various purposes. Modern scalpels with thin replaceable blades are not always good for this purpose, as the blades do not have sufficient weight.



Obviously, considerable experience and practice are necessary to gain expert control over such manipulations. Although the method is slow and tedious compared with the use of solvents, very precise work may be done; films of varnish and paint can be taken off without disturbing delicate glazes or scumblings, and dirt or varnish may be safely removed from the most intricate surface irregularities. Even a fraction of a film may be removed, and the depth of scraping is at all times entirely under control. For the removal of maculae and small, thick areas of varnish from an otherwise clean surface, this method is the only satisfactory one.

When it is used by a person of limited experience, the errors which are likely to ensue will usually be much less serious in extent and nature and much more easily corrected than those caused by an inexpert use of solvents. The blades must be constantly sharpened on an Arkansas oil stone during their use. The scraping is ordinarily done dry; an occasional wiping of the picture with cotton moistened with a liquid inert to the materials being worked on will bring out the colours, if desired. In some special instances it may be advisable to soften a heavy, oily coating with solvent before using the knife.

Mould (Mildew)

Exposure to strong sunlight (or ultraviolet light) and fresh air usually destroys and stops the growth of mould on fabrics. Provided a painting will withstand a cautious application of water, mould may usually be removed from its surface by rubbing with absorbent cotton moistened with a 10% solution of magnesium fluosilicate (silico-fluoride), rinsing off the solution afterward with cotton moistened with distilled water. This method will leave a minute amount of the chemical on the surface, which will guard against the recurrence of mould. Make sure the substance is really mould by examining it with a microscope or magnifying glass, because whitened varnish or oil and crystallized or powdered salts are often mistaken for it. Some other fungicides are mentioned under *Preservatives*.

Mould is a kind of fungus, the spores of which thrive on sized fabrics, glue, paint films, wood, etc., and once it flourishes, it will spread to adjacent surfaces of nearly any nature. Mould begins as a white, feathery growth, developing quickly into a denser and more or less coloured substance, depending upon its species. The commonest types are *Penicillium*, usually green, and *Aspergillus*, usually black or blackish, but many other varieties also occur. Various materials will grow certain types more rapidly than others.

The growth of fungi is encouraged by warm, humid, dark surroundings, and occurs most frequently on paintings which have been boxed and stored in the hold of a ship. It also flourishes in liquid paints, aqueous solutions of gums, etc. Mould should not be confused with bacteria.

Filling in Holes and Tears

After a painting has been relined and cleaned, or a damaged spot backed up with a patch, the holes, slits and flaked areas must be filled up level with the surface. In England this process is called stopping. Two general types of plastic material are in use, an aqueous glue plaster of the order of gesso, and a linseed oil-whiting mixture similar to common putty. The use of commercially prepared crack-fillers (both those sold as plastics with a varnish base, and the dry powders intended to be mixed with water) is inadvisable, not only because of their doubtful composition but, chiefly, because of their extreme hardness when dry. In general, materials which dry to a very hard consistency are not so good as those which are somewhat softer than the surrounding paint film; they seem to be less permanently adhesive and more liable to crack.

Another method of filling in places where the canvas is missing is to procure a piece of canvas of identical weave, lay it face up beneath the damaged spot, and with a keen, pointed blade cut around the tear or hole, just trimming off its edges, and at the same time cutting through the new piece of canvas. This will produce a patch or canvas plug which will fit the hole exactly. Such plugs must be used at the time when the patch or relining is applied. Great care and dexterity are necessary to get good results with this

method; the weave of the patch must line up accurately with the weave of the original canvas.

If a flawless job is desired, every spot where the paint or ground has become detached from otherwise intact canvas must be filled in before repainting, but in ordinary cases, superficial scratches and minor flakings are often touched up without first being filled in.

Plastic Gesso. Dissolve ½ ounce of casein in 3½ fluid ounces of water, according to any of the instructions under *Casein Solutions*. Emulsify with ¾ fluid ounce of damar varnish by shaking together in a bottle; mix to the stiffest possible paste with whiting or chalk as required, using a spatula or stiff palette knife on the rubbing slab. Other glue and casein gesso formulas may be used, with or without oil or varnish additions, according to the user's preferences, so long as they are made in the stiffest possible form with as little water as possible to minimize shrinkage, and so long as they comply with other obvious requirements. Is it not advisable to use plastics which are deliberately formulated to give a crackled effect; if such imitation of the defects of the picture is required, it is best produced by carving with a needle or by other artificial means. Pigments may be added to the whiting if it is desired to match any special colour.

Imitation of Textures. When the gesso plug is nearly dry and almost completely set, soft enough to receive impressions but firm enough so that pressure will not pick it up, a piece of cloth or canvas which matches or closely approximates the weave of the original canvas is pressed upon it in order that the texture of the repaired spot will be the same as that of the surrounding parts of the painting. Restorers can save for this purpose scraps from the edges of canvases they have relined, and sometimes one is able to steal a small scrap from the edge of the stretcher without harm.

All attempts to match weaves and textures require great care. Even a fairly smooth picture will require some roughening of a gesso plug to prevent a slick shininess. It may be pointed out that pressure of cloth produces a reverse or negative of its weave which sometimes appears very different from the surrounding area.

Picture Putty. Rub stand oil with whiting or chalk to a stiff paste with a spatula, then knead in more chalk by hand, rolling the putty between the palms; this is a rather sticky job at the start, but with a little practice one can do it efficiently, using dry chalk as a baker uses flour. The rolling warms the mass and softens it so that more chalk can be folded in until the mass becomes less sticky; finally, the stiffest sort of putty is produced. If desired, a few drops of syrupy cobalt linoleate added to the oil will make this material dry more rapidly.

One of the heavy white pigments (zinc or titanium) should be added to the chalk in sufficient amount to produce an opaque colour; also, any pigment or mixture of pigments may be added to produce useful shades. The bulk of the filler, however, should be chalk or whiting, which reacts definitely with the oil to form a putty-like mass, and which also imparts a desirable texture.

The paste may be moulded into conveniently shaped pieces and kept in

tight jars; the wrinkled skin which forms on the surface is peeled off before use. There is no danger that such wrinkling will occur in the small and comparatively thin layers in which the putty is used on pictures. This material is to be employed where more flexibility is required than the gesso plug presents. Canvas weaves may be imprinted upon it the same as upon the gesso plugs; this may be done as soon as the putty is smoothed. Whiting or other pigment may be dusted on the putty with the finger to prevent it from adhering to the cloth, should this be found necessary. Picture putty may be applied over a first layer of gesso, if desired.

Manipulations. The manipulations involved in the stoppage or filling in of lacunae, may be facilitated by the use of a good many types of instruments. Doerner[38] recommends kneading a plastic putty into tiny pills and rolls and pressing them in with the fingers, allowing them to set partially and then wiping off the excess with a well-wrung cloth which has been dipped into copaiba balsam thinned with turpentine. All traces of excess putty are to be removed from the surrounding parts at once. The area is also to be slightly moistened with the balsam mixture before the plastic is used.

I find that certain small blades and surgical instruments are invaluable for this sort of work—particularly the angular keratome, an eye instrument which is, in effect, a miniature triangular trowel set at an angle at the end of a thin handle (No. 3 on page 348). It is made in three sizes, the smallest of which is the most useful. This instrument should be of the best tempered steel, and before it can be used the two edges of the blade, especially the left-hand one, must be ground and sharpened to a keen cutting edge, all or most of the bevelling to be done on the top side in order not to interfere with the flat, trowel-like undersurface. Any type of plastic material may be applied with this, pressed and worked into the spaces, smoothed, and then, provided the edge is keen, sliced off level with the paint film while it is still in a plastic state. The instrument has been described in so much detail because it serves a number of other useful purposes in the studio or workshop. The smoothing of a sticky or tacky material with palette knife or any other flat instrument is often made easy by dipping the blade in some liquid: water, alcohol, or the copaiba mixture.

Repainting

Before touching up the blank areas of gesso patches, these highly absorbent spots must be treated with very thin shellac carefully applied with a finely pointed brush until the surface shows an incipient gloss; otherwise the absorbent dull spot will persist after repainting and even after the varnishing of the picture. Applying the shellac before the plug is thoroughly dry may cause it to crack. If tempera repaints are used to touch up such spots in an oil painting, they should be sized with damar in order to give them the same resistance to absorption of varnish as the rest of the picture has. The oil-putty type of plug does not require this treatment.

Obviously the new painting material must not turn yellow, or rather, it

should accompany the rest of the paint film in such changes as are likely to take place, and here the restorer must judge for himself. An average, fairly new oil painting may be matched in this respect by squeezing oil colours on to unglazed paper which will absorb the excess oil, and then mixing them with one of the glaze mediums (page 162). When tempera colours are used, there will be little or no change with time, but the restorer must know exactly how the colour is going to match when dry. Some restorers paint one approximate coat in tempera and a second or glazing coat with dry colours mixed with non-yellowing glaze medium. A great many methods suggest themselves.

A patch can seldom be made to match with one coat, even when this is stippled on carefully so as not to run over the edges, because of the difference in the colour of the grounds, and other optical circumstances. If the colour is first matched approximately, preferably keeping on the light side, it will generally be found that a second coat can be made to match the picture exactly. Some of the manipulations described under *Glazing* are useful for this work.

In all operations of the type just discussed, the object of the restoration must be taken into account. Curators of valuable collections sometimes desire the restoration to be unnoticeable when the picture is viewed in the ordinary manner and at the same time easily distinguished from the original work when examined closely; in other cases the blemishes are required to be entirely concealed. Repaints are also mentioned on pages 330 and 347.

Published Instructions. Some writers on the conservation and restoration of paintings are given to making statements which are more or less true in a general way, but which may be wrongly interpreted and often lead to misunderstandings.

A good many solvents and mixtures have been recommended as materials which will dissolve and remove the varnish and dirt from old paintings without dissolving the underpaintings; others are condemned because their action is so violent as to remove everything at once.

As a matter of fact, there is no universal, fool-proof liquid whose action is selective enough to remove varnish and automatically stop at the colour layer in all cases; some are merely more amenable to careful expert manipulation than others. In other words, these recommended solvents should be described rather as being more useful than the others to the expert worker in his efforts to remove only the top layers of old varnish, leaving the colour coat undisturbed (preferably, in the average case, with a minute trace of old varnish still adhering to it). The more violent solvents are those whose solvent action happens to be of such a nature that they will not respond to such expert handling but will continue to remove everything with which they are brought into contact, too rapidly to be controlled by the special technique the experienced picture cleaner has developed.

The behaviour of volatile solvents is purely mechanical, while that of water solutions such as soap or mildly alkaline compounds usually involves chemical action. Sometimes writers who warn against skinning a picture

will recommend such water solutions, but their effect is almost certain to be the entire removal of all traces of the varnish. In fact, as a general rule, they come closer to being automatic or selective solvents than the alcohols or ethers; but after they have destroyed the old varnish film, skinned the picture, and stopped short of picking up colour, they will immediately begin their less apparent destruction of the oil paint film, attacking it chemically so as to make it weak and spongy, altering the colour effect by causing a sort of permanent bloom, seeping into cracks and destroying the adhesion, etc.

The mistake of assuming that a faulty condition under discussion is the sole defect of a painting and thus ignoring the existence of complications which would contra-indicate the proposed remedy, has been referred to previously.

Theoretically sound materials, such as colours ground in pure damar varnish, are often recommended without taking into consideration the obstacles to manual execution which are involved and which are sometimes very difficult to overcome.

Floating Signatures. Writers on the authentication of old pictures refer to a test of the genuineness of a signature. When the painting has been signed by the original artist the signature will usually be part of the paint film; when the signature has been applied at a much later date over the varnish, or in paint of different or much newer materials, it is said to be a 'floating signature'. When a solvent is applied to such a picture, dissolving the varnish but not removing any paint, it can readily be discovered whether the signature was painted along with the picture in the same materials or whether it was added later.

Obviously, certain conditions must be taken into consideration: it can easily be understood that in some instances even a floating signature may be genuine; but in the great majority of cases, particularly when there are other reasons for suspicion, it is taken as conclusive evidence of fraud.

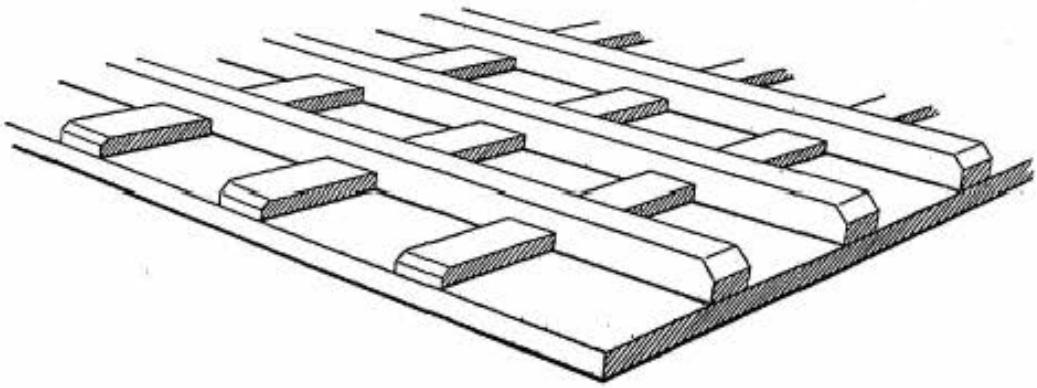
A restorer as such is less concerned with this aspect of floating brush strokes than with the problem of their preservation. While it is often necessary to remove fraudulent or undesirable overpainting and signatures, and while this work calls for considerable skill, understanding, and a comprehension of what is to be expected in the original underpainting, so many unorthodox methods have been used in painting that the restorer is often called upon to preserve legitimate floating brush strokes which will be considerably more affected by solvents than the rest of the painting.

Among examples of this sort of painting are the fine lines of the rigging of ships, which in some instances seem to have been ruled with a fine brush or pen over an isolating varnish, and delicate touches, scumbles, and glazes on portraits, clouds, foliage, and water, which have been applied over an isolating varnish so that free work and corrections would be possible during application without danger to the underpainting. The use of megilp, the addition of resin to oil colours, and other unorthodox or experimental techniques on the part of the original artist, offer complications which present themselves suddenly during cleaning and which serve to reinforce the rule

that paintings of any value should be restored only by highly qualified and experienced workers.

Cradling Old Panels

When the wood of a panel picture splits, warps, or is in danger of this type of disintegration, it is made sound and permanently conserved by cradling, that is, by gluing crisscross strips of wood to its back under pressure so that not only is the condition remedied, but the panel is strengthened and preserved against future decay. Like many other procedures of its kind, this is simple enough in theory, but must be executed in an expert and conscientious manner; if a specialist is not available the actual work may be done by any competent cabinet maker, amateur or professional, but the decision as to whether or not the panel should be cradled, and if so, to what extent, should be made by an experienced person. Most old panels are improved by cradling, but some have been injured by further complex warping and splitting despite being cradled.



The method consists of gluing mahogany or oak strips, about $\frac{5}{8} \times 1\frac{1}{4}$ inches, to the back of the panel, laying them on edge, about two inches apart for the average panel, and parallel with the grain of the wood, which usually runs parallel to the long sides of the picture. A strong hot glue or casein adhesive is used. At intervals of the same distance that separates these strips, they are slotted so that the cross strips can lie flat against the panel. These cross strips are not to be glued down, but must be able to move when the panel contracts or expands. They are usually about half as high as the strips through which they run.

The panel must remain under the pressure of clamps during the setting of the glue; in order to insure firm setting, it is usually left in the clamps several days longer than is usual in adhesive procedure. Regardless of how the method is simplified or altered, as in the case of works of minor value, by diminishing the number of strips, making them wider, etc., it should always be understood that the cross strips are not to be fastened; otherwise, more serious splitting or buckling will take place. Sometimes new panels of thin wood are cradled so that they will resist conditions they may be called upon to endure.

The cross strips, which are laid flat, may measure about $\frac{1}{2} \times 1\frac{1}{2}$ inches; the dimensions of both kinds of strips are subject to much variation, according to conditions. Formerly the prime consideration was a flat, neat-looking job; present opinion is that the stationary strips should be rather high to insure rigidity.

It has also been suggested that thin panels be mounted on heavy plywood panels on the theory that the thicker the support, the less effect warping will have on the picture. I do not know of any record proving the value of this over a period of years. Contrary to popular opinion, the complete painting or varnishing of back and edges to prevent absorption of moisture is not always advisable, as it may encourage dry-rotting of the wood; the end grain at least should be left uncoated so that air has access to it. As in other conservation procedures, a complexity of defects will sometimes result in conditions that demand special treatments. Very thick panels may be planed down; severely warped panels must be put under pressure carefully and gradually; a decrepit condition of the paint and ground layer often creates additional complications.

Wood worms or beetles in panels and furniture are easily destroyed by the application of carbon bisulphide. This is a much recommended material, the vapours of which are non-injurious to paintings, but its actual contact with paint is to be avoided, as it is a powerful volatile solvent. The technical grades have a disagreeable odour, which, however, is non-residual; the pure or C.P. grade is less unpleasant. The material is inflammable, but a mixture of 20 parts with 80 parts of carbon tetrachloride is non-inflammable. The carbon tetrachloride has considerable toxic action in this case and is not entirely a diluent.

Varnishing Pictures

The application of a thin, uniform, flawless coat of varnish, especially on a smooth old painting, is not the easiest process connected with oil paintings. Varnishes are best applied with a spray-gun; because they are comparatively thin liquids and do not need much air pressure, inferior machines are often used, but best results are obtained with a high-class modern gun which will deliver a well-atomized, fan-shaped spray. Some of those in use for industrial lacquer-spraying have traps to prevent condensed moisture or dirt from the air-source from mixing with the varnish. Most varnishing, however, is still done with brushes.

The optical effect of a heavy, glassy coat of varnish is not desirable in the light of present standards of taste, and the thinnest film that will produce a satisfactory, uniform surface is in accordance with the most correct practice from every viewpoint. A heavy coat of varnish is actually less durable than a normally thin coat and is more subject to various forms of decay. Also because of its contraction upon drying, a heavy coat applied over old or weak paintings is liable to cause eventual damage to the underlying paint which it is designed to preserve.

Varnishing is best done in a warm, dry place. Clear, windy days are best; humid or muggy days in midsummer are worst. In cold weather, varnish, brush, and picture sometimes require enough warming to take the chill out of them. The varnish is diluted with its solvent to exactly the proper consistency for best results (determined by experience, or, if it is a new material, by experimental trial). The brush should be a wide, flat bristle varnish brush of the best quality obtainable; uniformity or symmetry of thickness and freedom from shedding bristles are the two principal requirements. Some experienced varnishers prefer a softer brush, and use one of oxhair or red sable. Some prefer a rather thick brush, while others cannot get one thin enough. The thin or sparse brush is perhaps better, because it will not deposit such thick laps at the edges of the strokes; furthermore, it seems to do better work with less effort. If I were to have a special brush made either for varnishing or for applying gesso, it would be a three- or four-inch regular artists' flat bristle brush, possibly somewhat thinner than the average 'flat', but of about the same quality, and with the same incurving ends. These are largely matters of personal preference; varnishing is essentially an operation for which one must acquire the knack, and the tools are of secondary importance. Recommendations as to how to brush out a thin coat of varnish or flow on a heavy one, are similar to the previously criticized instructions for restoring, in that conditions vary so much. The following procedure may be entirely opposed by those who prefer other techniques.

The brush is dipped completely into the varnish once and then, depending upon one's experience and judgment, both sides of it and sometimes the edges are wiped off on the edge of the container so that just enough varnish remains in the brush to deposit a film of the desired thickness across the picture for 1 or 2 brush widths. After the varnish has been spread over part of the picture, or, in the case of a small picture, over all of it, a second application of the empty brush is made all over with a short, back-and-forth wrist motion in order to work the varnish well into the canvas weave; then a rapid single-stroke one-way brushing is done at right angles to the previous brushing to distribute the varnish more equally and to minimize laps in the first stroking; lastly, there is a straight, extremely light, rather slow brushing in the original direction with the brush held very flat, as a finishing or smoothing manipulation.

In our modern cities it is seldom possible to work in a dust-free atmosphere unless a specially constructed and air-conditioned room is available, and the warning to guard against dust as much as possible will be anticipated. After the varnish on a painting has dried for about ten minutes or as long as it takes for it to become set so that it will not run, the picture may be leaned at an angle, face against the wall, to finish drying. There may be some circulation of air, but no direct draughts. In a reasonably clean place there will be small danger of the picture's acquiring much dust in this position; coarse dust will not settle upward, but a swirling current of air might carry it upward against the picture.

It is not possible to apply a brush coating of varnish to a painting in a

vertical position without sagging or frilling of the varnish; the defects known as curtains, tears, streamlines, etc., are practically unavoidable. However, pictures can be so varnished by an expert use of the spray-gun, provided one is thoroughly familiar with the particular varnish being used, and is able by the correct spraying manipulations to avoid the above-mentioned defects as well as the unpleasant 'orange peel' effect which sometimes results. Toch[102] has devised a method of making balls of absorbent cotton covered with well-washed old lint-free sheeting, dipping these into a dilute varnish, and applying an even coating to a painting in situ, as French polish is applied. Usually only one very thin coat may be thus put on, and it does not take well on all types of paintings. The varnish recommended for this purpose is damar in turpentine plus 10% of stand oil, thinned down considerably with a mixture of half turpentine and half mineral spirit. This treatment is most effective on paintings which are in fairly good condition, where the greatest defect is a dulling or blooming of an otherwise intact surface.

As mentioned under *Varnishes*, damar is first choice as a picture varnish; mastic is easier to apply in a flawless coating but will turn yellow and is more likely to bloom. None of the other materials so far developed are in a class with these two. Flat (mat) finishes should be tested for yellowing, for non-polishing when rubbed, and for streaky or greyish effects on dark or deep-toned paintings. Pyroxylin (cellulose) lacquers and industrial varnishes made from synthetic resins contain a variety of oils and plasticizers; they become brittle and lifeless with age, turn yellow, and are too far removed in general properties from the materials used in the average oil or tempera painting. Perhaps their greatest disadvantage is their insolubility in the normal painters' solvents; most of them require the paint-remover type of solvent and therefore present complications both in application to and in removal from paint films. Some modern synthetic varnishes which can be freely thinned and dissolved with mineral spirit or turpentine have recently been placed on the market. Their behaviour is generally satisfactory when subjected to laboratory tests; more complete confidence may be placed in them after their composition has been studied and they have had a little more use under actual painting conditions. (See page 151.)

Removal of Bloom from Varnished Paintings. As mentioned in the discussion of varnishes on page 143, a mild surface bloom is not a serious or permanent defect when it occurs on a well-varnished painting. It may be removed from a picture which is well protected by an unbroken film of varnish by placing a few drops of light machine oil (such as is sold in small oil-cans for household use) on a flat folded Kleenex tissue and rubbing the picture's surface with small circular and back-and-forth strokes, using as firm a pressure as the canvas will take without injury. The oil should remove the bloom immediately, but satisfactory technique calls for evenly distributing the smallest possible amount of oil on the surface, and rubbing should be continued until all excess oil is absorbed back into the tissue. Certain types of cloth may also be used; a soft, coarsely knitted cotton generally known in house-furnishing departments as an absorbent floor cloth works well, but

some experimenting is necessary before using untried fabrics; the requirements for such a cloth are that it should not scratch the varnish or deposit lint, and that it should absorb and retain excess oil. If one doubts the quality of the prepared oils on the market, a satisfactory material can be made by mixing six parts of de-bloomed paraffin oil with three parts of olive or rapeseed oil and one part of highest-quality kerosene. Although these materials do not affect a varnish film, they must be used with discretion and never applied to a cracked paint film which is not thoroughly protected by an intact coat of varnish, or to an unvarnished painting, because the oil might cause damage if it were allowed to soak into the canvas or paint. Freshly applied varnish must be thoroughly dried, preferably for several weeks, before such treatments are applied.

Photographic Records

All works of art should be photographed before and after any extensive cleaning, repairing, or restoring. Such photographs should be made in a professional manner and care must be taken to record the exact extent of the original damages, not exaggerating them, but at the same time making sure that the camera does not minimize them; in other words, the actual condition as observed on close examination should be depicted. In the case of important works, it is often necessary to make more than one photograph for this purpose: sometimes it is desirable to have a close-up of some unusual defect or a detail of the varnish or some other surface effect (that is, focusing on the surface of the film to show the condition of the varnish), as well as a deeper view of the actual picture disregarding the surface.

The record of the finished restoration should be made under identical photographic conditions (as to camera, film, lighting, and development) if it is to have any value for comparison purposes, and no attempt should be made to conceal blemishes which may purposely or unavoidably have been left in the finished work.

Framing Pictures

The universal habit of fastening canvases into frames with nails is not a good one; when the nails are driven into the stretchers at an angle so that their points enter the frames, it is a clumsy and difficult matter to remove them, and both stretchers and frames are often spoiled during the procedure. Driving nails halfway into the frames and bending them over the stretcher does not always hold the picture securely; also the nails are likely to scratch or damage other pictures and frames with which they may come in contact.

Small strips of brass called brass mending strips, measuring about 2 inches long and ½ inch wide, with a screw hole at either end, are obtainable in well-stocked hardware and chain stores. If an end of one of these strips is screwed to the frame with a half-inch brass screw, the end which extends over the stretcher will hold the picture in place securely and neatly; four,

six, or eight of these strips may be used. They are flexible enough so that if the stretcher is not flush with the frame, as is usually the case, they may be bent in such a way that the end which goes over the stretcher will lie flat and fit snugly. A screw can also be placed in the other hole so that the strip is fastened to the stretcher as well as to the frame, but this is not usually necessary. If brass strips are not rigid enough for some large pictures, iron ones can be used. Pictures can be removed from such frames and replaced any number of times without wear or damage.

Pictures on wooden panels will warp when improperly framed. If they fit into the frame too snugly all around there will not be sufficient room for expansion, and they may buckle and split. If they are not well braced in a strong frame, they will (unless they have been cradled) be subject to erratic warping. Two or three thin pieces of cork, slices from a bottle cork, placed along each edge of the picture and secured to the frame with small brads, can be arranged so they wedge the panel into the frame tightly; their resilience will take up any expansion or contraction which may occur. When the brass strips are used to fasten panels into frames, they should be bent so they press the panel firmly against the rebate.

One way of holding a thin panel securely and permanently in a frame is to drive double-pointed nails one-third of their length into the edges of the panel at frequent intervals. Cut and mitre the ends of four wooden strips, of the same thickness as the panel, so as to form a rectangle, the inner measurements of which are somewhat larger than those of the picture. These strips are affixed to the edges of the panel with the double pointed nails, each nail penetrating about one-third of its length into the strip and about one-third into the edge of the panel. The frame formed by the strips is then securely attached to the picture frame, which must, of course, have a wider rebate than usual. I have seen an American portrait on a thin fruit-wood panel framed in this manner, in perfect shape after more than a hundred years of storage under the most severely adverse conditions, where other panels had suffered badly.

Cleaning and Repairing Pictures on Paper

For this type of work an understanding of the properties and characteristics of paper and the nature of the materials which compose the picture is essential. Prints (the term being used here in the narrower sense, meaning pictures made by the customary offset or type-printing methods), etchings, lithographs, and line engravings, whether in black or in colours, are made with oily inks and can be wet in water without injury; therefore the easiest way to perform such operations as are required in cleaning and bleaching them, is often to immerse them in trays of water or solutions. It is needless to refer to the fragility and sensitivity of such pictures, particularly old ones, when they are wet, and it should scarcely be necessary to point out the care and delicacy with which they must be handled during operations; for this reason more than the usual attention must be given to order, system, and

convenience in the workroom, implements, and apparatus. Print papers, unlike the papers described under *Water Colour*, often contain a number of ingredients such as fillers, coatings, and extra amounts of size, added to impart desirable qualities.

There are a number of details of precaution to be observed. Many have been omitted here; some are analogous to those given in connection with the treatment of oil paintings; and others will be obvious to the intelligent worker. The best teacher of careful manipulations is a varied experience; worthless prints of considerable age are easy to obtain, and experiment on them is simpler and can be carried out more systematically than is the case with oil paintings.

Large trays of glass or acid-proof white enamel, such as are used by photographers, are employed; the wet paper is handled by placing under it a sheet of plate glass somewhat larger than the picture, but smaller than the tray or tank. When this is lifted from the bath the picture adheres to it, and after the liquid has drained off, blotting paper is carefully used to remove excess moisture, and the paper is allowed to dry on the glass. An adequate supply of largest-size white blotting paper is a necessity; also a set of smooth drawing boards, cardboards, or Presdwood in various convenient sizes. Wooden or metal screw clamps, flat, wide camel-hair and hogs-hair brushes for paste and for washes, a wide rubber roller, sponges, tweezers, etc., are a few of the miscellaneous articles indispensable in this work; others will occur to the restorer. A sink or tub with running water and a small rubber tube attachment are also essential.

The resistance of printing ink to water and to chemical solutions, and the apparent recovery of the paper after its wetting, must not lead one to suppose that such treatment may always be carried out without danger. The sizing with which many papers have been prepared may be entirely or partially washed away and may have to be replaced before retouching or restoring can be done; some papers are made of two or more plies or sheets of paper pressed together; these will sometimes separate or at least blister when immersed in water. Should such multiple sheets become blistered or partially separated, a prolonged soaking in a tub of water will generally allow one to strip off the extra plies, and the thin sheet with the picture may be remounted on good drawing paper or cardboard. It should be superfluous to add that in all such separating operations, including the removal of old mountings from prints, etc., two layers should never be forcibly pulled from each other; no separation should be attempted until the paste or glue has been dampened to such an extent that the layers will come apart easily and with no trace of any damage to the fibres of the valuable layer.

Some Japanese prints, as well as some artists' proofs of coloured block prints, monotypes, etc., are made with aqueous paste-colours instead of with the more usual oily ink, and cannot always be immersed in water with safety; but they will usually stand a limited amount of cleaning if it is carried out correctly.

Cleaning and Bleaching

The first procedure in cleaning prints is to remove oily or greasy stains, if any, by applying a volatile solvent with absorbent cotton or a soft brush. Acetone and diacetone are good solvents, but according to the nature of the stains other solvents may be required. Carbon tetrachloride and petrol are the best wax solvents. Occasionally prints may be completely immersed in solvents if a cautious testing shows that their lines or colours are not affected by them. Those who are not familiar with the use of volatile solvents are advised to note their individual properties and the precautions to be observed in handling them, as discussed in the section devoted to them beginning on page 262.

According to Scott,[96] the best material for removing linseed-oil and paint stains of long standing is pure, colourless pyridine applied with a brush of glass fibres. Repeated applications, followed shortly after by removal of the liquid with blotting paper, will often either remove such spots or diminish them to such an extent that they are made inconspicuous. The print is allowed to dry until the odour of the pyridine has disappeared. Ordinary impure pyridine is a yellowish liquid with a highly disagreeable odour; it is used as an alcohol denaturant.

A coat of simple-solution varnish can usually be removed by immersing the print in alcohol, scrubbing it gently with a camel-hair brush while in the bath, rinsing with fresh alcohol, and drying. Weak ammonia water is also sometimes useful for this purpose. Oil or oleoresinous varnishes are seldom applied to prints; when they have been used they can seldom be removed without leaving blotchy remnants. Superficial dirt, pencil marks, etc., are removed with Artgum or soft bread pills.

The customary method of bleaching, cleaning, and removing common foxing or brown stains which resemble iron rust (but which are usually a species of mould), is to immerse the print in alternate solutions of bleaching powder and hydrochloric acid, the strength of these solutions to be kept dilute so that they will not harm the paper. The report quoted above recommends a ½ to 1% solution of bleaching powder, which will be ¼ to ½ ounce of powder to a quart of distilled water, and 1 fluid ounce of C.P. hydrochloric acid to a quart of water.

Many accounts of this process were published in a rather unscientific manner during the early years of the twentieth century; some writers recommend bleaching powder, others recommend concentrated ready-made solutions of both calcium hypochlorite and sodium hypochlorite, or Javelle water, which act alike. Another similar bleaching solution which has about the same action is Milton. The best procedure, taking into consideration the results, safety to the paper, and ease of control, is the following:

The print is immersed alternately, first in the acid and then in the bleach for 10–20 minute periods, until clean or until no further lightening is apparent, after which it is washed in running water for an hour or two. The print is handled on plate glass, as was described earlier; while wet it is very fragile.

Bleaching powder is popularly called chlorinated lime or chloride of lime, and is sold in a sufficiently pure grade in domestic stores; instructions for making Javelle water are printed on the containers.

Another bleaching process is the following, recommended by J. G. Goulinat;* it uses an oxidation-reduction reaction familiar to all chemists. The figures refer to grams of material and millilitres of water.

Immerse the print in a 5:1000 solution of potassium permanganate for several minutes; remove from tray, rinse off with water, and return to the permanganate solution to which has been added a 10:1000 solution of sodium thiosulphate (hypo); allow to soak for 10 minutes. Then add 10 drops of C.P. hydrochloric acid. When print is white, wash in running water for ½ hour, and dry. The print is handled on plate glass, as noted above. The action in this process is harsher and more drastic than that of the chlorinated bleaches. Exposure to sunlight, as recommended for oil paintings, is efficient, but is likely to fade some of the more fugitive inks and colours.

For applying bleaching action to pictures which will not withstand immersion in solutions, and particularly for restoring the original whiteness of high-lights and other spots on a drawing which has been touched up with white lead water colour, a recommended procedure is to make a flat plaster of Paris cast or tile, and after impregnating the porous surface of this with peroxide of hydrogen, to arrange the drawing or print with its face down ⅛ inch or so from the cast, whereupon the darkened areas are bleached in a few hours by the action of the peroxide. The same method may be used to treat other bleachable conditions. When the drawing or print is so sensitive to water that even moist vapours such as these will cause ill effects, as in the case of fragile mounted or unmounted India-paper prints, an ethereal solution of hydrogen peroxide is recommended. Ether is shaken with peroxide solution in a bottle, it extracts the peroxide from the water solution and floats on the top of the water in a well-defined layer. (See remarks, page 269 for, precautions in handling ether.) In connection with this procedure and with direct applications of hydrogen peroxide solution to paint surfaces which are partially but not entirely resistant to aqueous solutions, it has been found that the destructive effect of water is greatly diminished by addition of 50% of pure ethyl alcohol to the solution. Hydrogen peroxide is universally obtainable in 3 to 4% solutions, and also in a powerful 30% solution called Superoxol, which requires careful handling, as it attacks the skin.

Another method which is sometimes found effective (and one which does not appear to have been published) is to allow the fumes of a strong reaction of concentrated bleaching powder and acid to come into contact with such spots. A small swab of absorbent cotton fastened to a wooden applicator is dipped into rather concentrated hydrochloric acid (1:1) and then into a dish of dry bleaching powder, particles of which will adhere to it. While the fizzing reaction is still going on, the cotton is brought close to the darkened spots, whereupon the fumes effect rapid bleaching. The same materials may

* In the article, 'Paintings, Restoration and Preservation of,' in the *Encyclopædia Britannica*, 14th Edition.

be applied over a flat surface as in the preceding method, except that in this case glass instead of the acid-soluble plaster must be used.

Writing-ink stains are removed by the bleaching-powder process, which is the basis of most of the prepared ink eradicators. A more powerful remover of inks and similar stains is oxalic acid, a 10% solution of which may be applied with a glass rod. However, the application of chemicals without subsequent immersion in or thorough washing with water is not to be recommended; chemicals left behind in the paper weaken it and cause eventual staining. After every chemical treatment paper should be well washed in running water in the same way in which a photographer washes his pictures, and for the same reason.

Prints in storage will absorb atmospheric moisture, which is nearly as great an enemy to them as it is to oil paintings. Authorities on the conservation of prints consider it very important to sterilize them after the removal of mould marks. This is best accomplished by subjecting them to the vapours of thymol by placing them in a tight cabinet which contains a dish of thymol over the heat of an electric light bulb. The material is volatilized by allowing the light to remain on for two hours, after which the print is left in the cabinet for 24 hours longer. The procedure can be repeated as often as necessary without harm to paper or vellum, but printed surfaces may sometimes be spoiled by the solvent action of the fumes. This process, which is described in detail by Plenderleith,[103] does not give permanent protection against further infestation.

Antiquated recipes often recommend restaining the brilliant white paper of a cleaned print with solutions of tea, coffee, ale, tobacco, etc., or smoking it over a damp wood fire, in order to bring it back to a 'natural' aged appearance —a procedure not in accordance with modern practice or taste.

Very fragile pictures, prints on India paper or Japanese tissue, and pictures done in soluble or sensitive line or colour which will not withstand immersion, may be treated from the rear by pressing upon them blotting paper impregnated with the solutions, or may be pressed between two nearly dried blotters. The disadvantage of this procedure is that only partial results are effected and badly blemished prints are not well cleaned or bleached; however, in some cases little else can be done.

Pastels. The restoration of pastels requires delicate operations. As noted under *Pastel Painting*, they will survive a limited amount of pressure in contact with glossy paper or cellophane so long as there is no lateral movement, but every precaution should be taken to avoid rubbing their surfaces. A layer of dust can often be removed with a blast of air, and I find that sometimes, but not always, a careful light contact with a sheet of paper coated with a very slight, well-dried film of rubber cement will result in the dust's being picked up without too much removal of colour. Tears can be plugged by mounting the picture, cutting out a patch from paper of the same thickness and texture, and proceeding as in the case of canvas plugs for oil paintings. These patches can be tinted with water colour before being coated with pastel; all repainting and matching of colours will require very careful preliminary

selection of crayons and usually the manufacture of special shades. It is not a difficult matter to retouch and smooth out blemishes if one has learned the manipulations of applying pastel, and with a picture that has been done in an average good thickness of colour (as the early portraits usually were), minor spots can often be smoothed out with a delicate handling of a leather stump.

Beaufort[99] recommends cleaning and bleaching a pastel by taking it through most of the operations to which prints are subjected, from the rear, carefully floating the picture on the surface of the solutions and the water, if necessary attaching its edges to narrow strips of thin cork with drawing pins. A sheet of strong drawing paper is used as a support in place of the plate glass, and after a preliminary floating on water to remove creases, the print is picked up with the drawing paper and floated for a few minutes on a very weak solution of Javelle water or other single-solution bleach. As a final treatment, the pastel on its drawing-paper support is placed in a tray and its surface gently flooded with water for a few moments, after which it is removed and carefully dried.

Water Colours. As water-colour painters know, the average completely dried water-colour painting will withstand a careful and not too prolonged rinsing in water provided it is not rubbed while wet. Bleaching coloured pictures or pictures on coloured paper is not to be undertaken thoughtlessly; many colours and coloured inks, especially the older ones, are susceptible. Retouching of mended water colours is done with weak colours in a stippling manner with the point of a small, nearly dry brush. In the case of any picture on paper, when the sizing needs replacement for purposes of retouching, a very dilute solution of gelatin is best—a half-ounce or less to a gallon of water.

12

Miscellaneous Notes

Notes on Perspective

The surface of a picture is a plane figure of two dimensions bounded by the frame, and any lines or masses depicted upon it lie within that plane and have only length and breadth. Aesthetically, a two-dimensional picture or design may be entirely successful, but the development of most schools of art has led to a demand for perspective or a means of creating upon a two-dimensional surface the effect of three dimensions.

Perspective in a picture is a sort of optical illusion perceived by virtue of training and education and made possible by certain mechanisms (sometimes called defects) of the human eye. It is therefore an artificial system evolved for the purpose of creating an effect, and as such it must follow arbitrary rules and laws.

The rules of our system of perspective apply principles which have been worked out by geometry; however, exact perspective as studied by mathematicians is not strictly applied to the usual pictorial technique, but only such basic points as are of practical value. Writers on the subject have always gone to great lengths to point this out and to make the artist aware that according to his artistic intentions he must consciously decide for himself just how far the construction of his drawing should follow mathematically produced points, and just where these points should serve as guides for selective approximations, so that the result may be the work of his own hand and not an example of applied mechanics.

The present account is a short outline, for reference purposes, of a few of the basic geometric constructions, selected for their simplicity and practical application; for a more thorough study, the reader is referred to the complete manuals on perspective, where the relationship of these basic rules to artistic purposes is shown.

Application of Perspective to Pictures. A defect of our system of perspective from the mathematical point of view is that a vanishing point is really accurate only when the subject is viewed from one point or station and when the line of vision is trained directly on one point of the scene. Artists seldom attempt to secure extreme mathematical accuracy in all parts of a complex drawing; the reason for special care and accuracy in the guide lines or underpainting is that the artist may thereby guard against too great an error in perspective, the assumption being that one is necessarily bound to deviate somewhat from mathematical accuracy during creative work, and that the

more accurate the guide lines the easier it will be to keep within the bounds of acceptably correct drawing or to control deviations at will. Whether or not distortion, or departure from realistic perspective, is advisable is entirely the concern of the artist himself; but it is almost universally expected, according to the general ideas on art at present, that such effects will be deliberate and controlled rather than accidental.

Some kinds of painting are not concerned with perspective or third-dimensional relationships, but we have become so imbued with the third-dimensional feeling that it influences most of our works.

Aerial Perspective. In nature, the distant parts of a landscape assume a less brilliant colour than the objects in the foreground; they are often made hazy or given a bluish-white tone by the volume of atmospheric moisture through which they are viewed. This effect may be directly translated to a picture without the use of rules or laws other than those which can be learned by observation of natural phenomena. Other elements being equal, objects have a tendency to become cooler in colour (to move away from the

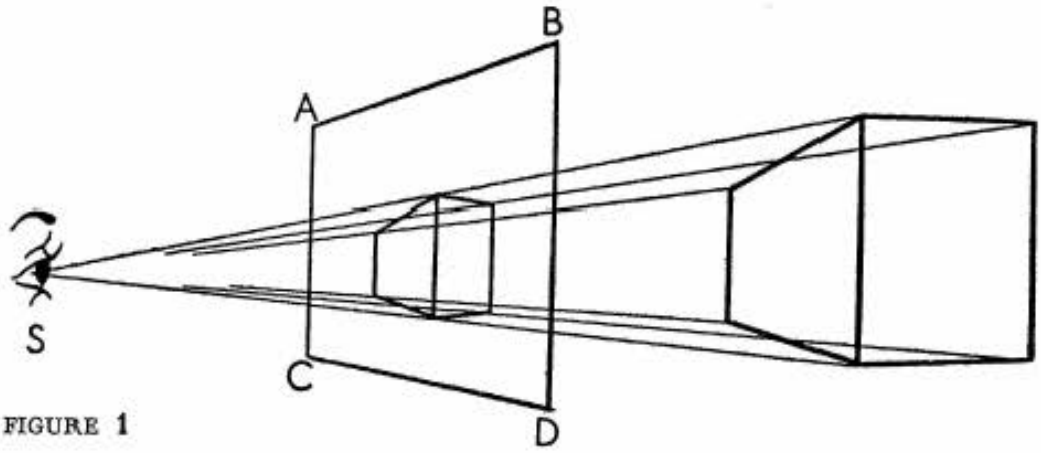


FIGURE 1

red-orange-yellow side of the spectrum and toward the green-blue-violet side) as they recede; this change may be depicted by mixing more white or pale pigment with the colours. In black and white pictures, bold contrast is used in the foreground and greys and blending tones in the distances. The Chinese and Japanese painters utilized this method of depicting recession by interposing mists and aerial softening in some of their monochrome landscapes.

Linear Perspective. We observe, in addition to these colour changes, that objects in the background appear to diminish in size as they recede, that parallel lines appear to converge, and that horizontal lines assume various angles. Depending upon our degree of skill, we are able to approximate these relationships, so that our drawings appear more or less correct according to our impressions, by the application of a geometric perspective which conforms to established rules. An *isometric drawing* is one in which each dimension of an object is represented in its actual measurement or proportion. This method is sometimes used in mechanical drawing and mathematics, but it gives a distorted view of the object, whereas a drawing in true perspective

of the *apparent* dimensions, though not in accordance with actual measurements, gives a true impression of the object as viewed.

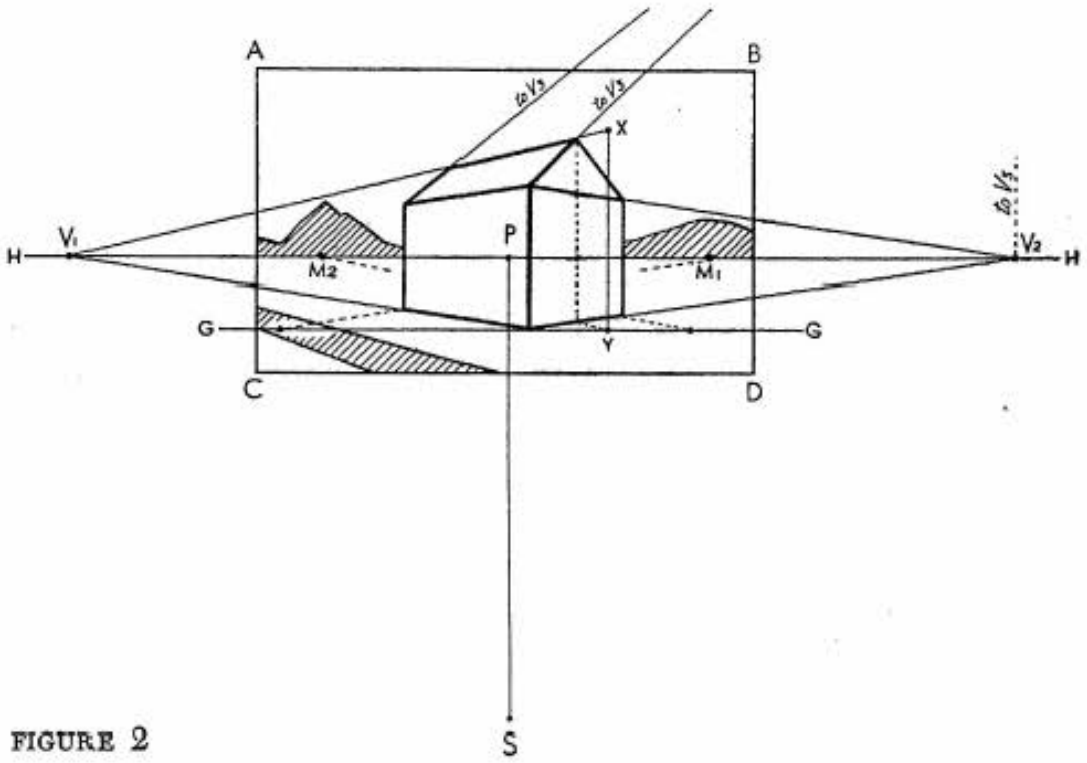


FIGURE 2

The terms used in these notes are those universally employed in reference to the construction of perspective drawings. Observer refers to the artist, or original observer of the scene; spectator refers to the person looking at the finished picture.

Picture Plane (ABCD in figure 1). An imaginary transparent plane interposed between the subject and the eye of the observer, as if it were a sheet of glass, through which the cone of vision passes, converging upon the observer's eye. This plane corresponds to the surface of the picture.

Cone of Vision. A term used occasionally in the explanation of perspective, especially when the eye is compared to a camera lens. The light rays reflected by the subject pass through the picture plane and converge upon the eye; they are depicted as imaginary straight lines which form a conical design, and they delineate the perspective points on the picture plane as they pass through it.

Horizon Line (HH). A construction line drawn across the picture plane, parallel with its upper and lower sides. In a landscape it is usually somewhere near the centre; in a sea view it would be the actual horizon; in any landscape it may vary in position, depending upon the nature of the scene and its significant objects, but it is always on a level with the eye of the observer. For purposes of perspective construction it is sometimes necessary to extend the horizon line beyond the picture on either or both sides.

Point of Station (S). The point which corresponds to the eye of the ob-

server, fixed in front of and opposite the middle of the horizon line, at a distance varying according to the requirements of the picture and the judgment of the artist. This point is normally about as close to the picture as one can stand and take in the whole view comfortably. The distance is not selected according to any strict rule, but should depend mostly upon the width of the angle of view of the subject. One traditional method is to construct an inverted equilateral triangle on the horizon line of the picture and use its apex as the station point. Another familiar procedure is to make the distance slightly less than the width of the picture. The station point is the basis of mathematical perspective. Because it is fixed, placed outside the picture plane, and accurate only when used as if a person were sighting along a line with one eye, some of the flaws of a purely mathematical perspective as applied to

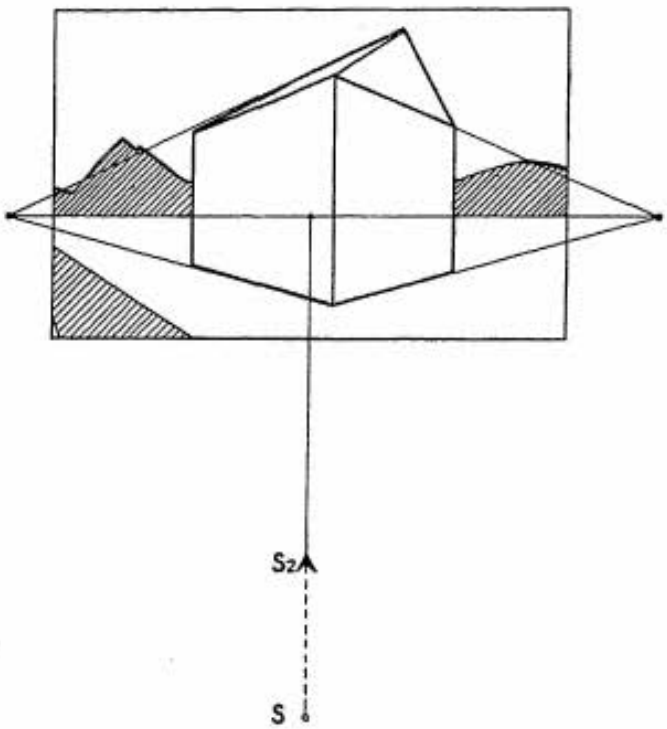


FIGURE 3

artistic purposes are evident. Almost every painting contains more than one system of lines, and spectators view it from many points. In figure 1, the eye corresponds to the station point; in constructing a drawing the artist makes a simple diagram, for convenience swinging the station point down, placing it below the picture plane, as in figure 2. If the distance between station point and picture plane is shortened, that is, if the observer moves forward the recession of background will be more violent and objects in the foreground will loom up. If the distance is lengthened, that is, if the observer moves backward, the recession will be more gradual and the scene will be flattened out. Raising this point on the diagram is equivalent to coming nearer to the subject; lowering it is the same as retreating in order to include more foreground, as the constructions which follow will show.

Point of Sight (*P*). The point on the horizon line opposite the eye or station point.

Line of Vision (*SP*). A straight line drawn from the station point to the point of sight.

Parallel Perspective and Oblique Perspective. When a side of an object is parallel to the picture plane and when the line of vision is exactly in its centre, the object is said to be in parallel perspective; when the object is turned, it is in oblique or angular perspective. Figures 7 and 9 are in parallel perspective and figures 2 and 3 are in oblique perspective.

Ground Line. The base or lower boundary of a picture plane. The term may also be applied to a similar construction line used anywhere in the

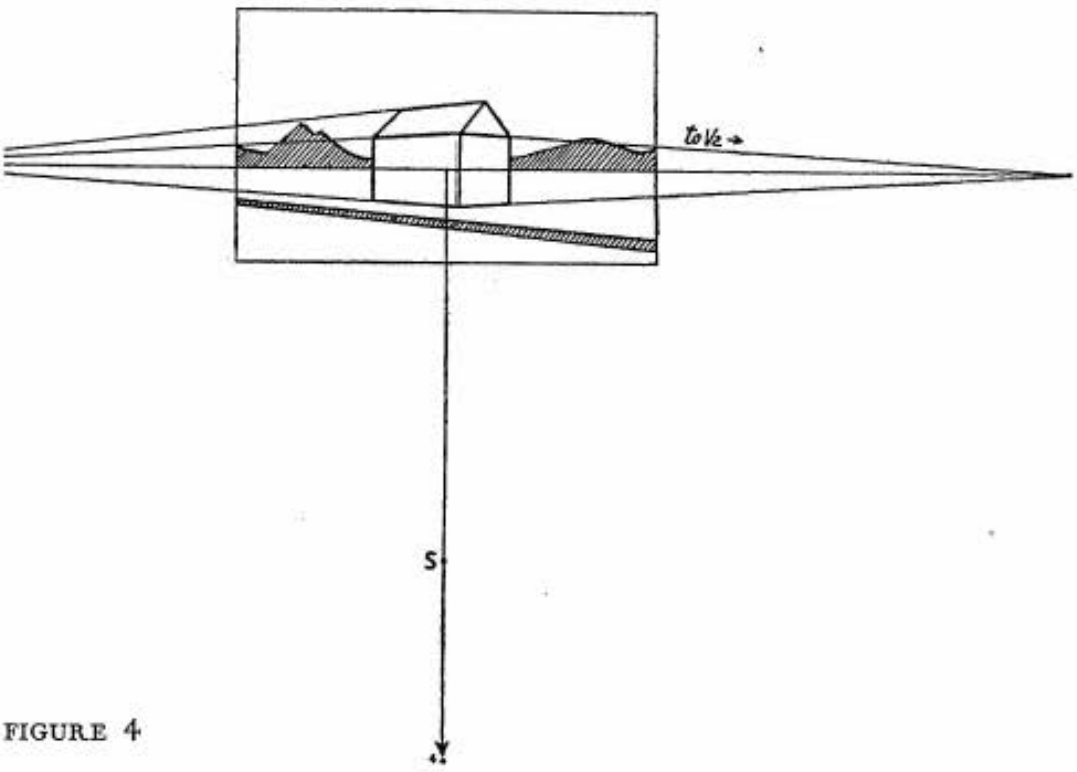


FIGURE 4

picture to measure off points or to determine the scale of a figure, in which case it should preferably be called a scale or scale line (CD; also GG; see figure 2).

Vanishing Points (V_1, V_2). The lines which lie in a plane of any single object or group of objects, if extended toward the horizon, will meet at a point in infinite distance; in a picture, the point on the horizon line where they apparently converge is called the vanishing point. Depending upon the directions in which the planes face, a scene may have many or few vanishing points. Figures 7 and 9 are in parallel perspective and therefore each has but one vanishing point, the point of sight. The other figures are in oblique perspective and have a vanishing point on either side of the point of sight. Lines above the horizon line always converge downward to it; those below the horizon line converge upward to it. Lines which lie on a plane parallel to the

picture plane do not approach the horizon line and therefore do not converge. For example, the sides and rungs of a perpendicular ladder which faces the observer do not converge; if they appear to, the line of sight has been shifted and they no longer lie on a plane perpendicular to it. Lines such as the edges of some sloping roofs and stairways do not lie in planes parallel to the horizon line in the actual scene, and their points of convergence do not lie on the horizon line but meet at a point directly above a vanishing point (V_3, figure 2), or, if downward, below it. When lines are drawn from S to the two vanishing points of a rectangular figure they always form a 90° or right angle.

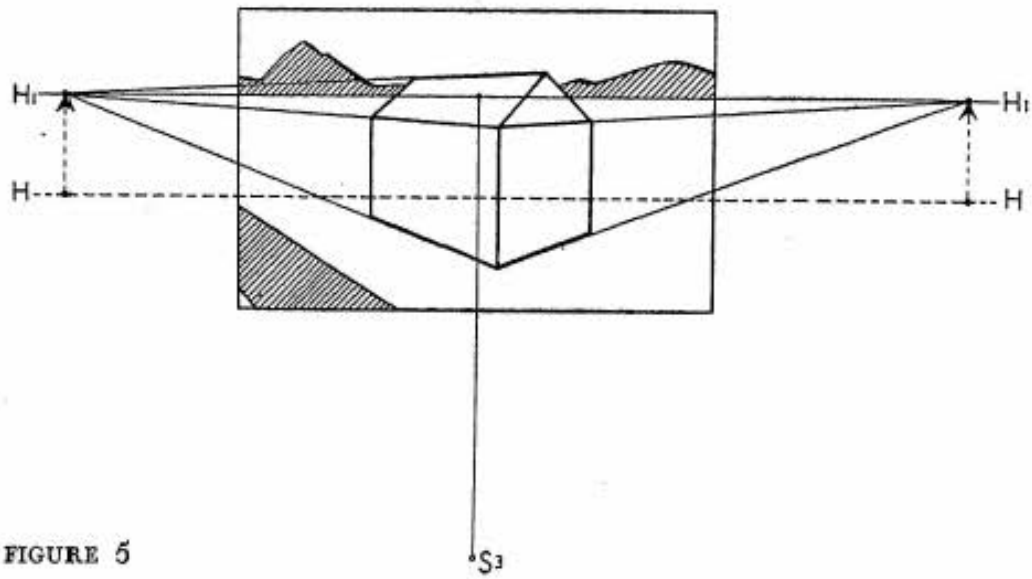


FIGURE 5

Figure 2 shows most of the construction lines and points discussed above.

Figure 3 shows what happens in this scene when the observer moves forward, raising the station point from S to S_2.

Figure 4 shows what happens when the observer moves back, lowering the station point from S to S_4.

Figure 5 shows what happens when the observer moves to a higher level, raising the horizon line from HH to H_1H_1.

Figure 6 shows the result of shifting the station point to the left.

Lines of Measurement. In order to locate the depth of objects in recession or to determine the distance between objects which recede at regular intervals, lines of measurement are used. A line of measurement is found by laying off a point on the horizon line using a vanishing point as a centre and the distance between it and the station point as a radius. A line drawn from this *point of measurement* to a point on the ground line is a line of measurement.

One of the most convenient methods for placing objects in recession is to mark off a crisscross or checkerboard pattern of squares on a ground plan or floor of the scene (figure 7). The usual procedure is to mark off the width of these squares on the base of the picture (the smaller they are made, the

more accuracy of detail can be obtained) and connect these points with the vanishing point. From the vanishing point, a point of measurement is established as described above, and the line of measurement MG is drawn to the opposite lower corner of the figure. The squares in perspective recession are then obtained by drawing horizontal lines through the points where this line intersects the convergent lines. If desired, another line of measurement may be drawn on the opposite side of the point of sight.

The line XY is the actual scale height of the objects. Some artists believe this method to be too mechanical, the recession sometimes being defective for its purpose—too sudden or too gradual—so they establish the points of measurement by trial or judgment instead of by actual measurement. If

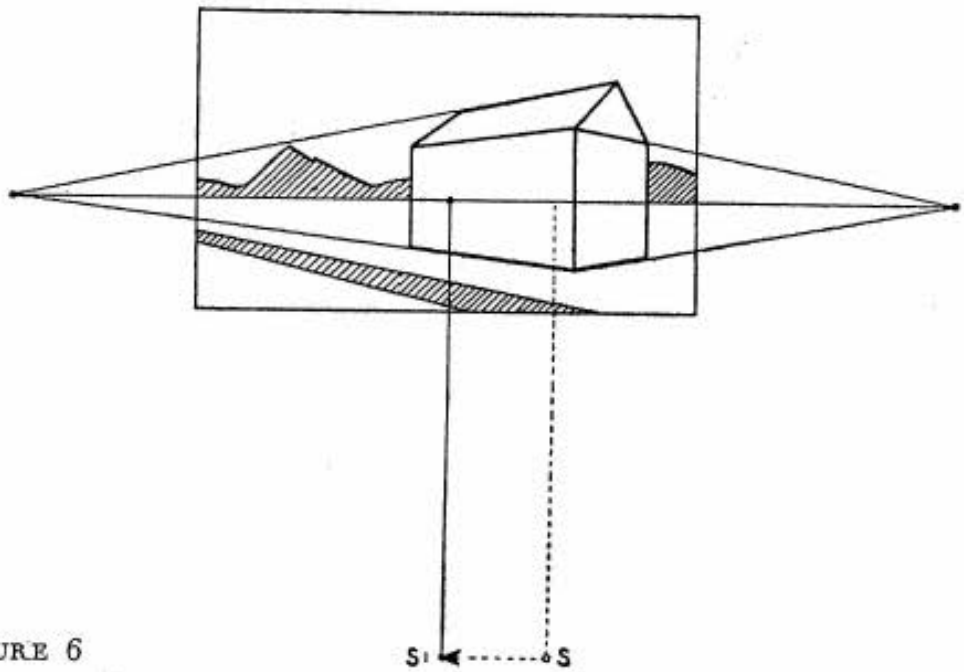


FIGURE 6

receding points are required in an area which is in oblique perspective, both vanishing points and both lines of measurement must be used and the lines of the squares are then determined by the two sets of intersections instead of being made parallel to the ground line.

Projection of a Ground Plan into Perspective. Figure 8 shows a method for the accurate projection of the ground plan of an object in oblique perspective; this method can be used when it is desired to project the ground plan in scale or proportion to actual measurements and in any size, either larger or smaller than the drawing of the ground plan. The rectangle F corresponds to the floor of the little house in the other diagrams, and the terms and principles discussed under those examples apply here.

First select the station point to conform with the direction and distance of the observer from the object. In this particular case the observer is slightly to the left and quite close to the nearest point of the object. Draw a vertical line upward from S. Draw a horizontal scale line (GG) at any convenient distance above the plane. If the object is part of a scene and it is desired to

insert it into a picture plane, the distance between d and GG will naturally have to be made great enough to accommodate the foreground. Draw a horizon line (HH) parallel to GG, and at a distance above it equal to the height of the observer's eye level, so that its intersection with the vertical line will be the point of sight (P). From S draw a line parallel to a side of the rectangle and another at a right angle to it, and use the intersections of these lines with the horizon line as vanishing points (V_1, V_2). Using these vanishing points as centres, locate the points of measurement according to previous instructions. The following basic elements of a perspective drawing have now been estab-

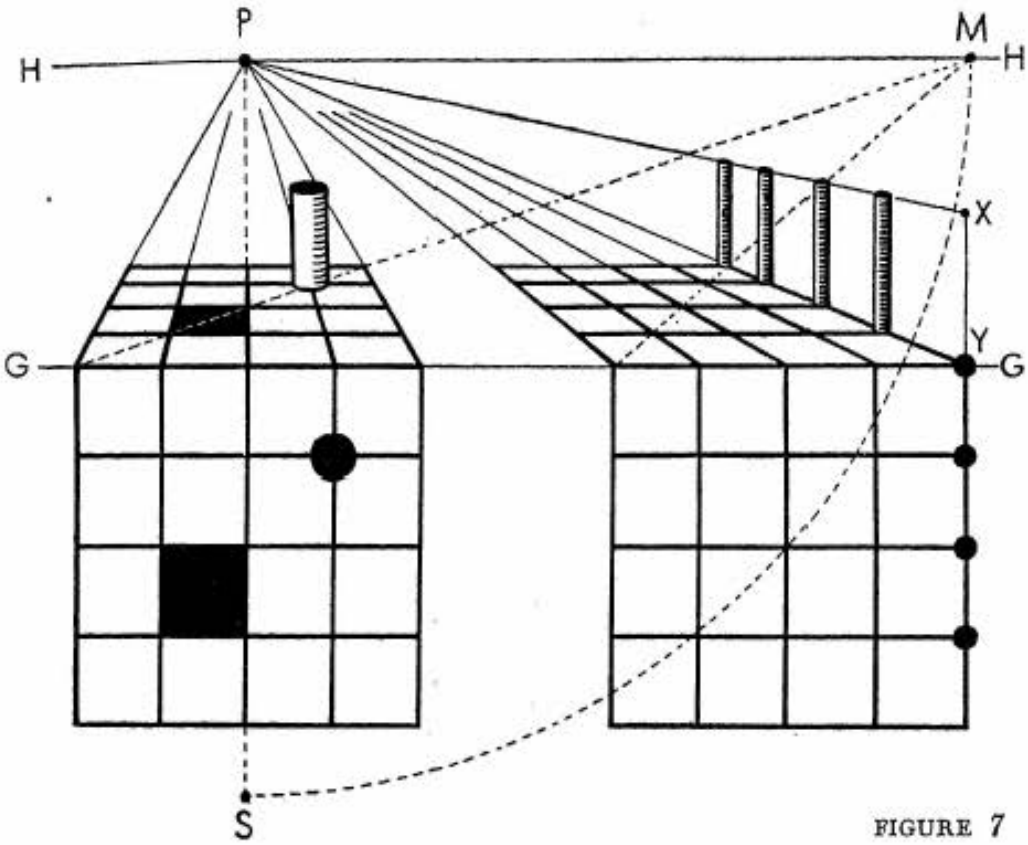


FIGURE 7

lished: station point, horizontal scale line, horizon line, vanishing points, point of sight, and points of measurement.

Draw a vertical line from the point of the ground plan nearest the observer (a) to the scale line GG, and draw lines from this point (a_1) to both vanishing points. From point a_1, lay off on the scale line the actual desired scale measurement of a–b and connect the point b_1 with its point of measurement M_1. Repeat this procedure on the other side of a_1, using the measurement a–c. From the point b_2, where the line of measurement from M_1 intersects the line from a_1 to its vanishing point, draw a line to the opposite vanishing point V_2. Repeat this procedure on the other side to locate c_2, and draw the line c_2–V_1. The rectangle a_1, b_2, d_1, c_2 is the projection of the ground plan F.

If the vertical line a–a_1 is extended upward from a_1, it will be a vertical

scale line for the object, and any scale measurement laid out upon it will establish the object's height or the height of details within its planes. A line drawn from a point of vertical measurement to a vanishing point will determine these heights in perspective. Such a line would correspond to the line XP in figure 7.

Circles and Curved Lines. The projection of curves in perspective is usually accomplished by reference to straight lines or rectangles; for example if a circle is to be placed in perspective, a square whose sides are the same length as the diameter of the circle is constructed below a ground or scale line, put into correct perspective, and the circle inscribed freehand within this rectangular shape, where it will assume the form of an ellipse. When the curved figure is more complex than a simple circle, it is sometimes convenient

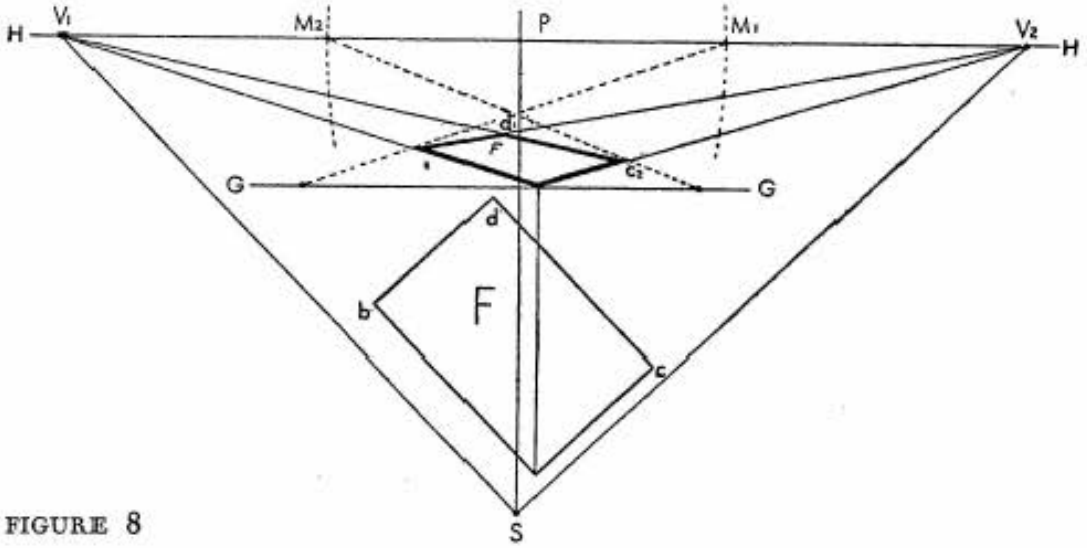


FIGURE 8

to block off the guide-figure in rectangles and refer to each section separately by an application of the checkerboard system. The final result will depend upon the skill and experience of the artist.

Sometimes it is desired to depict a circle in perspective with greater accuracy than can be obtained by drawing an ellipse freehand within the perspective square, or the circle is viewed at an unusual angle or has complexities of construction the drawing of which requires a little more guidance than that supplied by the perspective rectangle. Figure 9 is a fairly obvious illustration. One must determine the place where the forward edge of the circle in perspective is to come, and through that point draw a horizontal scale line. A square is laid off below this line, a circle inscribed within it, and diagonals are drawn upon it. The square is put into perspective by means of vanishing and measurement points, as previously described; the location of the far side of the figure is obtained by drawing a line, MG, from either point of measurement to the opposite upper corner of the square already constructed. When the perspective circle is to be inserted into a picture, the vanishing point of the plane upon which it lies must be used.

The lines of measurement will form the diagonals of the perspective square. A vertical line is drawn through the centre to the vanishing point, and another line through the centre at right angles to this. These lines meet the sides of the perspective rectangle at the points where the ellipse will be tangent to it. Draw vertical lines upward from the points where the circle intersects its diagonals, and connect the two points where these lines meet the scale line with the vanishing point. The intersections of these lines with the diagonals supply four more intermediate points, so that the ellipse may now be drawn with eight guide points. If the perspective rectangle is in

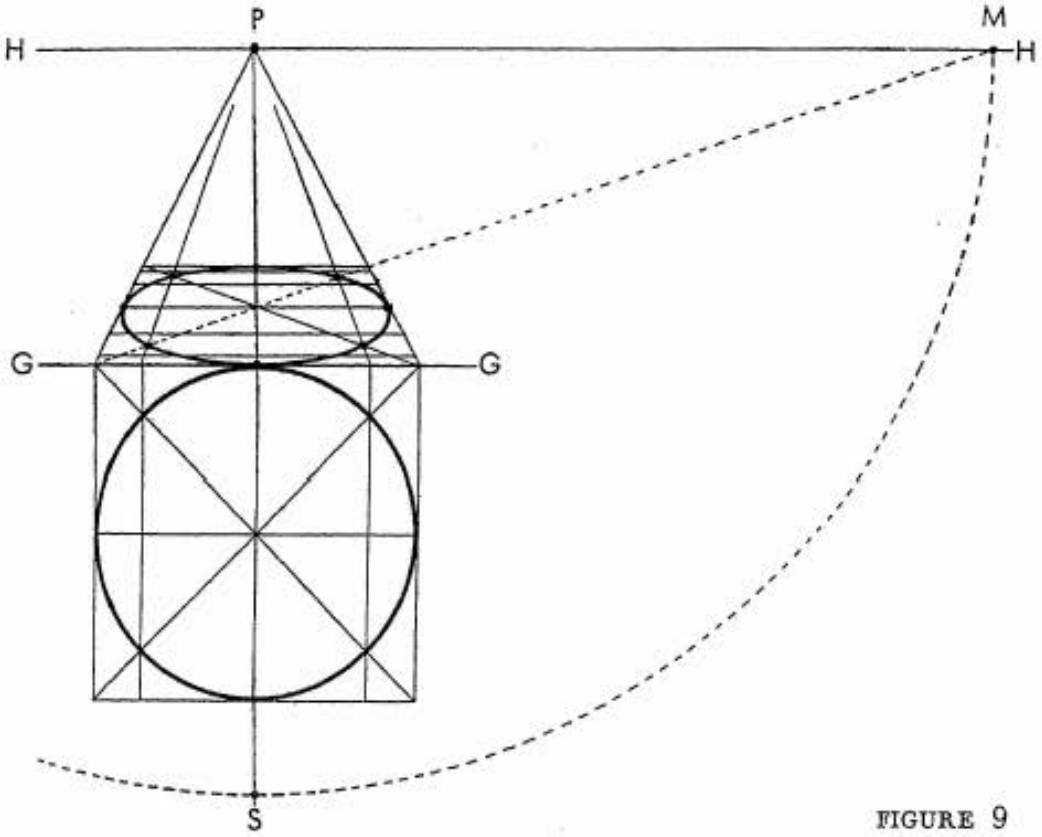


FIGURE 9

oblique perspective both points of measurement must be used and each of the two cross lines is drawn to a vanishing point instead of being at right angles to each other.

Notes on the Graphic Arts

The term graphic arts is in general use for designating all processes for the production of multiple-proof pictures on paper on a hand-made basis, the work being done either wholly or in most part by the original artist, and editions limited. The prints are ordinarily printed in black, occasionally in one colour, more rarely in multiple colours; and the individual copies or proofs are ordinarily numbered and signed by the artist, more often in pencil on the margin than on the plate itself. The term excludes all forms of

mechanically reproduced works photographed or redrawn on plates. However, some mechanical reproductions, especially the better ones of famous or popular paintings, are so well done and represent such a degree of technical skill that they are often valued as fine prints.

Japanese prints, for instance, have been condemned as works of art by certain connoisseurs and artists, especially by the Japanese, not only because they were originally works on popular subjects for distribution to the public, as distinguished from the more esoteric and precious paintings, but because their production was several steps removed from the work of the original artist and depended upon the co-operation of expert engravers and printers; they are now, however, as thoroughly accepted as the other forms of Japanese art.

The accepted graphic-arts processes are, in approximate order of their present-day popularity: lithography, etching, dry-point, wood cutting or wood engraving, aquatint, and soft-ground etching. Engraving on copper and steel, and mezzotint engraving are almost as obsolete in art as they are in commercial reproduction. They have their practitioners, but these are usually workers in other techniques who employ metal-plate engraving occasionally, rather than specialists who confine their major efforts to this medium. Although these processes were employed as art media in the past, their chief use was always in the multiple reproduction of paintings.

Copperplate etching has always enjoyed the position of an important if not a major art medium since the time of its mechanical perfection and improved control of effects, which date from the early seventeenth century. Early writers tell us that during the sixteenth century it was used in its first stages of development as a possible labour-saving substitute for engraving, attempts being made to subordinate its characteristic qualities in the interest of imitating engraved lines, rather than to exploit all its characteristics and evolve a unique tradition. The origin of etching has also been attributed to early metal workers and armourers who used it for decorative designs on metal.

The woodcut was the earliest form of multiple reproduction of pictures and designs, but it soon became obsolete for most purposes and was little used until its revival as an art medium in our own day. Wood engraving came into wide use as a means of reproduction and illustration during the middle of the nineteenth century, but newer reproduction methods introduced toward the beginning of the twentieth century caused it to become obsolete quite suddenly. Although the adaptability of its effects for certain work had caused it to be appreciated as an artistic medium to some extent during its life as a common means of reproduction, it was, with a few notable exceptions, never widely selected as an art medium until its twentieth-century revival as such. Woodcuts and wood engravings are often called block prints, to distinguish them from the metal-plate prints. The two groups are inked differently. The metal-plate processes, etching and line-engraving, are incised or intaglio processes; the ink is applied to the plate and wiped off, the lines being left charged with ink, which is deposited on the paper by running plate and paper through a roller press in contact with each other. The wood

blocks are inked by a roller which deposits a coating of ink on the raised surfaces; this in turn is deposited upon the paper by vertical pressure. Other characteristics which distinguish the effects of the various processes are: etched lines do not taper and expand as engraved or pen-drawn lines do, but are always the same width throughout; the grain of lithograph and aquatint masses and the fine lines of etching masses disclose more of the paper than the solid block print does, thereby imparting more granulation or depth to the print.

Limited Editions. The usual opinion is that proofs of the highest degree of excellence may be obtained only in limited editions, owing to sacrifices in finesse which must be made when a durable, lasting plate for quantity production is required.

A considerable group of present-day artists and commentators on art, however, point out that the graphic-arts processes were originally adopted not only for their sympathetic rendering of line, form, and tonal effects, but equally as much for the multiplication and consequent distribution of proofs. They claim that the limitation of editions by destruction of the plates or by the adoption of techniques and effects not capable of resisting for long the wear of continued impressions, is a comparatively recent development, and one fostered by artists and dealers for monetary reasons. They call the resulting rarity of such prints artificial, and cite the case of lithography, where the works of modern living artists command higher prices because of their scarcity than the proofs of some accepted masters of the nineteenth century whose works were turned out in fairly large editions. Although anxious to develop good craftsmanship, they are willing to sacrifice the attainment of superlative technical results if these require such delicate plates and time-consuming printing manipulations that large editions sold at low prices are out of the question.

On the other hand, the artist who, by great application and development along individual or personal lines, is capable of producing superlative proofs, continues to produce them in strictly limited editions. The term superlative proofs here implies prints which completely and thoroughly fulfil the most exacting requirements of perfection of control over the medium both in relation to the artist's intentions and from the viewpoint of the fullest textural qualities inherent in the medium itself.

This question, although it is not a purely technical one, must influence an artist in his choice of technique as it involves details and various adaptations of the graphic-arts processes. New standards of excellence, both artistic and technical, always become established with the development of any new methods and materials, and in their own way they become just as complete artistic expressions as the older traditional standards.

LITHOGRAPHY

Lithography was invented in Munich in 1798 by Aloys Senefelder, and thereafter came into wide use both as an artistic medium and as a means of reproducing pictures for publication.

Simply outlined, the process consists of drawing or painting with greasy crayons and inks on a particular species of limestone which has been ground down to the desired texture. After several subsequent manipulations, the stone is well moistened with water, whereupon the parts not covered by the crayon become wet, while the areas where the greasy drawing was made repel the water and remain dry. An oily ink is then applied with a roller; it adheres only to the drawing, being repelled by the wet parts of the stone. The print made by pressing paper against the inked drawing is not a reproduction in the same sense as is the mechanically reproduced print, but it is a true autographic replica, in reverse, of the original drawing on stone. The direct manner in which the drawing is made and the range of tones which can be obtained, make the process popular. Lithography is classified as a planographic or flat-surface process, as distinguished from the other graphic-arts processes, which are either intaglio or relief.

Lithography, unlike etching, enables the artist to confine his efforts to the execution of the drawing; because the printing is a somewhat mechanical procedure, the object of which is to turn out exact copies of the drawing as it appears on the stone, the great majority of artists have this work done by professional lithographers. However, it is generally considered necessary for the artist to have mastered the actual procedure involved in the printing process while learning lithography, in order to be thoroughly familiar with its requirements. Considerable knowledge and proficiency is required for the production of fine prints, and the number of professional artist-lithographers who can turn out really superior proofs from the stones entrusted to them is limited. This is particularly true in work which involves any great delicacy of tone or line. Some artists will carry their effort to secure completely faithful replicas of their original drawings to the point of having the prints made on paper of a tint that matches the original grey or tan colour of the stone.

The autographic quality of lithography is not always emphasized by some lithographers; for instance, Brown,[56] who based his instructions on the artist's carrying out every phase of the process himself, regarded the final proof as the principal consideration. In one case he worked on the introduction of a development whereby a new tonal effect was added during the printing process. Unless the printer is an accomplished expert, very sensitive or delicate tonal effects must be sacrificed.

Lithography is widely used as a means of commercial reproduction, and although the basic principles are unchanged, many variations in technique are used by industrial lithographic establishments. The artist has small concern with these procedures; none of them improve and most of them detract from the quality of the work from an artistic viewpoint, for the aims of the industrial lithographer are not those of the artist, and the commercial lithograph is definitely a reproduction, not an artist's proof. Practically every artists' lithographic process in use today was known, at least in principle, to the inventor and early workers of the craft.

Lithograph Stones. The limestone from Solnhoffen, Bavaria, with which Senefelder first perfected his original process, is the best. Many substitutes

are quarried in various parts of the world, but all are inferior. The best-quality stones are those of a grey or 'blue' colour. The yellow or tan stones appear to be of a softer or looser texture and not capable of taking such a satisfactory grain; also delicate work done on them is more likely to be injured during the printing process; nevertheless, some artists express a preference for them. Stones which show any colour variation are usually rejected, as streaks or spots indicate a variation in composition or texture which may interfere with the printing; but many such defects do not show in the final prints. A small stone, 10×12 inches, is about $2\frac{1}{2}$ inches thick and weighs about 30 pounds. For perfect proofs and to prevent breakage in certain types of presses, the thickness must be accurately uniform. The larger stones are made proportionately thicker; a stone measuring 18×22 inches will be approximately 3 inches thick and will weigh about 100 pounds.

The artist does not require many stones, as they are ordinarily cleaned and refinished as soon as an edition has been pulled, although the stone with its original drawing may be preserved for several years, if desired. The great majority of artists, especially those to whom lithography is a minor or occasional activity, own no stones but rent them from the printer or supply house, where they have the graining and resurfacing done. Few maintain their own presses, and a good proportion of the finishing and printing work they do is carried on outside their studios, in workshops of professional artist-lithographers, in art schools, artists' societies, and occasionally in an industrial lithographic shop. Much of the best work is done by artists under such conditions, with the close co-operation and supervision of professional printers, the best of whom are not only artists in their own right but sympathetic to and co-operative with the aims of the artist who makes use of their professional services. Although every material used throughout the technique is available ready-made in adequate quality, there are always a number of experimental-minded artists who make their own crayons and other materials, and who are constantly striving for improvements in the drawing and printing of their work.

Metal Plates. Plates made of zinc or aluminium, light in weight and just thick enough to be rigid, have long been in use to supplant the more cumbersome stones; in industrial lithography they have practically replaced them. They are sold ready-grained to imitate the texture of stone, and also in a variety of other grains for various types of artistic and reproduction purposes.

The technique of using metal plates is not basically very different from that applied to work on stone, but there are naturally many points of variation in manipulations. In the case of metal plates, the possible manipulations are more limited in number and are somewhat more difficult to master. Often, because of the darker tone of the zinc, the artist is led into the production of more contrast than he would create on the paler stone. An expert can ordinarily distinguish at once between proofs made from plates and those made from stones; those made from stones are universally considered to be superior, and although some artists find the plates adequate for some types of work, the stone retains its position as the standard material among artists.

Graining. The grain is imparted to the stone by grinding its surface with flint, sand, or other abrasives. The stones are finished by laying two of them face to face and grinding them with the abrasive and water. Metal plates are grained by machine; the grains of abrasive are tumbled upon their surfaces with small balls or marbles. Zinc plates do not act well when old; they should be freshly prepared, and protected against atmosphere and moisture until used.

Transfer Lithography. In order to overcome some of the limitations of lithography as compared with other methods of pictorial production, artists have for many years made lithographs in an indirect manner, by drawing with lithographic crayons on paper. These drawings, which are obviously made without many of the disadvantages and limitations attendant upon work done directly on the cumbersome stones or inflexible plates, are sent to the printer, who, by a rather simple process, transfers them to a stone or plate and turns out final proofs which are not reversed—that is, the picture is reversed when it is transferred to the stone, and the prints taken from the stone reverse it again so that they reproduce the original point for point.

In average hands, the resulting proofs are greatly inferior to those obtained by direct drawing on the stone or plate, and a person of any experience at all can detect the difference immediately. For simple sketches or simple black and white contrasts they often suffice, but for work of any degree of delicacy the process is not to be recommended to the average artist; in fact, it has been claimed that such prints should not be called lithographs. On the other hand, very fine results have been obtained with transfer papers, especially by the leading print-makers of the late nineteenth century, who were conscientious students of the process. By the use of specially coated transfer papers, work of considerable finesse and delicacy has been transferred to zinc plates with much success by experienced specialists.

Specially prepared and coated transfer papers can be purchased in two varieties: a thin tracing paper and a thick chalk paper. These papers have a grain which takes the crayon in a way that superficially resembles the effect produced by the average coarse-grained stone. The undesirable textures of the drawing in the final proof are caused partly by the fact that a reverse image or negative of the original textures of the crayon marks is deposited on the plate or stone in place of the textures caused by the stone itself in the direct method. Regardless of superficial resemblances in the textures produced, drawing with crayon on paper, as explained on page 17, is somewhat different, both in the mechanical action involved and in the results obtained, from drawing on stone or plate, the tooth of which is tiny pits rather than matted webs. The mechanical handling of the transfer will also contribute to loss in textural quality, although expert manipulation can keep such changes to a minimum.

The directions and precautions to be observed in making the drawing are practically the same as those for drawing on stone. The paper must be kept free from grease. Not so much freedom in manipulating the crayon is possible. The principal advantage of transfer over direct lithography is that an easily transportable pad or portfolio is available for rapid sketches.

Despite the superiorities of direct work on stone, large numbers of transfer prints are continually being produced. The results obtained by the use of coated papers approach the original lithographic quality more nearly than do those obtained with the common tracing papers.

Drawing on Stone. In most instances preliminary drawings or sketches the exact size of the print are made on paper and traced faintly on the stone as a guide to the drawing. The usual tracing material, to be rubbed or drawn on the back of the paper, is sanguine crayon which contains no grease, has no effect on the stone, and because of its red colour will not become confused with the black drawing. Some lithographers prefer soft lead-pencil lines. If too many chalk or lead-pencil lines are put on the stone, they may clog the grain and interfere with the action of the lithographic crayon.

The greatest care must be taken to keep the stone absolutely free from greasy impurities and adherent dust. Breathing upon the cool stone causes condensation of moisture, through which the crayon slides badly. One must never touch the sensitive surface with the fingers; in order to prevent smudging some convenient form of bridge may be used as a hand rest. A stave from a small barrel or keg is the simplest one.

The main point to be observed in regard to the drawing is to apply the crayon with the proper touch to obtain the desired effect. The normal lithograph texture is the granular one produced by more or less minute portions of the paper showing through the black printing ink, even in the heavy black areas. The crayon is dragged across the surface with a sensitive touch; if rubbed back and forth with a heavy hand, it would tend to fill up or overload the texture of the stone so that dull, coarse blacks would be produced instead of the luminous sparkle. The use of flat areas of tusche (mentioned below), or of benzol or other solvent, will create dead flat printing areas; such effects may of course be desired at times, but the normal technique avoids them. The use of a knife, a pointed rod of abrasive material, a hard ink eraser, and many improvised tools for scratching out or producing special results, is learned by practice and experiment; the extent to which one may employ very delicate effects depends upon the capabilities of the printer and is a matter of individual discovery. The variations in texture attainable by manipulation of the crayon are seemingly unlimited.

The Crayon. The two main requirements for a satisfactory crayon are: it should be of the proper degree of hardness to produce the desired mass or line effect on the surface and to work in a sympathetic manner; it should contain a correct blend of materials so as to deposit the necessary grease-receptive water-repellent printing areas. Crayons in the form of square sticks about 2 inches in length, as well as those in pencil form, are universally sold in an adequate range of hardness: No. 0, very soft; No. 1, soft; No. 2, medium; No. 3, hard; No. 4, very hard; No. 5, copal. Miller[61] recommends Nos. 3 and 4 for most uses, and the softer ones for use in cold weather only; he disapproves of No. 5 entirely. The crayons which are intended to be used in the customary crayon-holder or portcrayon and sharpened to suit exact requirements are sometimes considered more professional than the pencils,

which are perhaps easier and more convenient for the majority of artists; but this may be prejudice. Fine points are best made by sharpening with a thin blade from the point toward the holder rather than away from the holder in the manner of sharpening a lead pencil.

An inky liquid which contains the ingredients of the crayon in liquid form is much used for pen and brush work, and to produce solid blacks. This is called tusche,* never, correctly, lithographic ink; the latter name applies only to the printing ink employed to produce the final proofs, and its use in reference to tusche leads to confusion.

Lithographic crayons and tusche are always black, regardless of the colour in which the final proof is to be printed, because the drawing is judged and the printing manipulations regulated according to experience gained by working with black; a litho crayon made with a red pigment, for example, would distort all of the practitioner's judgment, based as it is on the black and white technique. Lampblack is used in crayons because it works well, is of the correct texture, and does not interfere with the functioning of the process.

Although the ready-made materials are of acceptable quality for normal practice, a few lithographers prefer to make their own, believing that they obtain superior results from special formulas. The following selected recipes are typical of the average materials in use:

Senefelder's Recipes	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Wax	4	8	4	8	8	8	8
Soap	6	4	4	4	5	5	6
Lampblack	2	2	2	2	3	3	3
Spermaceti			4	4			
Shellac					4	4	
Tallow						2	4

After being melted in a shallow pan in the order given, the blended materials are ignited and allowed to burn for a minute or so; then the flame is extinguished by covering the vessel. This procedure is repeated many times, and imparts hardness to the crayons. Upon cooling, the mass is cut or sawn into convenient pieces.

The lithographer who is interested in making his own crayons to meet various requirements will seldom be satisfied to copy old recipes, as commercial brands of crayons can be had to match the properties of most of these, but he will usually wish to do further experimenting. Brown[56] lists

* Not a customary term in Britain, the liquid is known here as lithographic drawing ink.

nearly a hundred formulas in his book and mentions some additional raw materials. The following are the properties which various raw materials will impart to the crayons. The chemical réactions of lithography are noted on page 326.

Ingredients which deposit strong printing areas:

Tallow—imparts softness and greasiness.
Stearic acid—imparts comparatively granular, non-sticky quality.
Oleic acid—softness, greasiness.
Palm oil—softness.

Ingredients which deposit less strong printing areas:

Beeswax—smoothness, adhesiveness.
Carnauba wax—hardness.
Japan wax—softness, some stickiness, adhesiveness.
Linseed oil—greasiness and softness.

Ingredients which have weak printing action:

Soap—smooth or slippery quality; also solubility in water. Necessary in liquid tusche. Liberates free fatty acids when wetted with water. Crayons will print but will not manipulate or draw well without it.
Mastic and other resins—stickiness, solidity.
Shellac—hardness.

Ingredients which have no printing action; small amounts will impart fluidity, softness, or smoothness:

Paraffin wax.
White mineral oil.
Vaseline.

The sole function of the lampblack is supposed to be to colour the crayons, but it also contributes a little solidity and drag to their drawing qualities. The addition of lye partially saponifies the oils and fats, but under the conditions of the mixture probably does not make complete soaps of them.

Preparation of the Stone for Printing. First the edges of the picture are neatly ruled off and the margins of the stone are thoroughly cleaned with snakestone and water. A rather wide margin, at least two inches all around, is necessary for convenience in printing. The manipulations as outlined in the following paragraphs are usually carried out in the order given, but sometimes the order is varied; occasionally some procedures are omitted and some repeated more than once, according to the preferences of the printer.

The Etch. At the beginning of this section the lithographic process was outlined, and reference was made to intermediate steps between the making of the drawing and the inking of the stone. The principal one is the application of the etch.

When the drawing has been completed, its entire surface is gone over with an acidified solution of gum arabic, which deposits a film on the uninked portions and completely desensitizes the stone, making it incapable of further grease adsorption. This solution is called the etch, a misnomer carried over

from the very earliest experiments by the inventor of lithography, who at first attempted to produce relief and intaglio printing surfaces on the stone. The etch does not eat away the stone with the crayon acting as a resist, to produce a raised or relief printing surface. More accurately, it could be called a fixative or desensitizer; any smudges or accidental inkings of the blank portions of the stone will not take after the etch has been applied; the ink will be confined to the drawing.

Both the gum-arabic film and the one deposited by the crayon are tenacious and insoluble, and may be repeatedly sponged and rinsed with water and turpentine respectively without injury to their water- or grease-repelling properties, or to the definition of their areas.

The stone at this stage is thoroughly desensitized, and the first part of our original outline explanation must be somewhat elaborated; the process actually depends upon the fact that the greasy crayon sets up an insoluble, grease-attracting, water-repelling condition, and that the acidified gum solution or etch sets up a water-attracting, grease-repelling condition, not by the action of superficial, adherent films, but in the surface of the stone itself. Further remarks on this subject will be found in the section on chemistry (page 326). After the etch has been applied and the subsequent manipulations have been carried out, the portions of the stone that have not been drawn upon are so desensitized that even when the stone is dry, if printing ink is smeared on these areas, it may easily be washed off with a damp sponge. When the stone has been thoroughly wetted, no trace of ink will be taken from the inking roller by even the most minute points of exposed stone. The further manipulations referred to, although they may be considered minor refinements from the point of view of the general underlying principles of the process, are actually of great importance in securing perfect results, and the manner in which they are carried out governs the success or failure of the printing process.

A typical formula for etch to be used on stone contains gum arabic and nitric acid. Dissolve gum arabic in the proportion of 1 ounce to 2 or 3 fluid ounces of water, and add C.P. nitric acid in small amounts until a few drops of the mixture applied to the face of a stone just barely shows a definite bubbling action—about a teaspoonful to 3 or 4 ounces of solution, or about 1½ parts to a hundred, will be required. Too much acid is suspected of being a cause of loss of delicate tones in the final proofs. The concentration of the gum solution is not a matter that requires accurate measurement. For zinc plates the most frequently recommended etch is chromic acid in the same amounts, with the addition of 15 or 20 drops of phosphoric acid; for aluminium, the chromic acid is omitted.

The etch is applied liberally all over the stone with a sponge or wide camel-hair brush, and dried by fanning; after it is throroughly dry, it is washed off with a sponge and water. The stone is then given an application of plain gum-arabic solution, and again fanned dry.

The crayon drawing is next washed off with turpentine, whereupon the image seems completely destroyed, but the grease-attracting, water-

repelling condition that was set up in the stone is still there. The stone is then rubbed with a small amount of a weak asphalt solution, fanned dry, washed with water, and inked while wet.

The inking roller is a carefully made piece of equipment on the order of a wooden rolling pin, smoothly and tightly covered with fine calfskin over a layer of felt. Loose leather grips over the handles allow for control in manipulation. The manner in which this implement is cared for and used throughout the process is of great importance.

The stone is now cleaned of all accidental defects; the margins are made clean, and, if desired, minor corrections are made on the drawing. The inked stone is then well dusted with powdered rosin (to make it more acid-resisting), and is re-etched for a few minutes and washed off, after which the rest of the process is repeated. When the stone is finally ready to be inked for printing, it is placed on the bed of the press, and while thoroughly wet is inked with the roller; the prints are made by placing dampened paper on the stone, protecting it with a clean sheet of paper over which a piece of fibre board is laid. Pressure is applied by means of a lever, and a crank runs the stone under a greased, leather-covered wooden scraper, which transfers the inked drawing to the paper.

The crayon drawing is washed out because it is composed of waxes, soaps, and other ingredients not desired in the final printing, which is done with an ink made with thickened linseed oil. If the crayon drawing were allowed to remain, it would eventually be carried away by the proofs and the inking roller, but the dozen or more prints made while traces of it were still on the stone would be wasted, as they would be defective in tonal qualities. The crayon is formulated solely for its drawing properties and the action it causes in the stone; it is not wanted after these properties have been utilized and the lithographic condition has been set up in the surface of the stone.

The first inking or rolling-up of the stone is an important step in completely establishing the permanent grease-receptive condition of the printing area.

Printing or Lithographic Inks. Black and coloured printing inks differ from the colours sold in tubes for oil painting in that they must be ground to the very finest sort of grain and the most complete dispersion possible, by being repeatedly put through powerful and accurately adjusted roller mills. The consistency requirements differ from those of oil colours in that printing inks must be capable of depositing on the paper a smooth, level, uniform stain rather than a thick painty layer. The colour effect is generally that of water colour, the underlying white paper contributing brilliancy and luminosity to the tones; but opaque colour effects are not entirely unknown.

In order to meet these requirements the ink makers produce a very stiff paste, capable of being spread or rolled out to a level flat film on the inking roller, and having just the necessary degree of snap or sticky tackiness, combined with a certain oiliness. Specially made litho varnishes, which are heat-bodied linseed oils, are cooked for the purpose, and are commonly burned or ignited during the process; their viscosities and other physical properties are

closely controlled, and the various grades are standardized and sold by universally known numbers. Litho varnishes which are combinations of two or more viscosities are often called for in ink formulas, not because any exact viscosity desired could not be produced, but because such mixtures will give results that are different from any that can be obtained by the use of a single oil (see page 312).

An ink-reducer or extender is a diluting medium with which a printing ink can be made weaker in colour or more transparent without its body or working properties being altered. Prepared mixtures are sold for the purpose.

Lampblack can be ground in litho varnishes in the same way oil colours are made at home, but the resulting material would be inferior to the manufactured inks, the production of which requires a high degree of skill and powerful machinery.

ETCHING

Etching consists of drawing with a fine steel point, or needle, on a soot-blackened metal plate which has been coated with a ground of acid-resisting wax or varnish. In the true etching, the drawing does not depend upon any lines the needle may scratch on the plate; the lines merely cut through the wax, exposing the brightly polished metal. The plate is subsequently immersed in an acid bath, which bites out or etches the exposed lines.

After the etched plate is cleaned, it is inked, and prints are pulled from it on a special roller press. Editions of thirty to a hundred proofs are commonly pulled, after which the plate is customarily destroyed. Technically, the size of the edition is limited by the ability of the metal to endure the pressure, which eventually wears down the sharpness of the lines. If the plate is steel-faced or electroplated, clear, clean editions of several hundred proofs may be produced. The question of the number of proofs to be made involves several considerations, as discussed on page 376.

The wax coating or resist protects the surface of the plate and confines the action of the mordant to the sharply incised lines; but after this action has proceeded a very minute distance below the surface, there is nothing to prevent it from eating away the metal horizontally as well as downward. The result is that the etched line is an undercut affair; the edges of the lines have little solidity or support and will wear away with greater rapidity than will those of an engraving, whose grooves have walls which are straight-sided or bevelled.

Each step in the etching process is very largely mechanical, subject only partially to individual control; but the handling of all the stages and the manner in which they are combined, make for entirely individual and sensitive results; judged by any standards, etching is a true fine-arts medium. If any of the steps are simplified or made easier by too radical departures from the traditional methods, the results will usually display some lack in the qualities expected of an etching. Because the lines made by the needle are uniform in width and do not taper or expand as do those of an engraving or a

pen drawing, because the action of acid is uniform on every part of the exposed metal, and because the pressure of the roller press should be mechanically uniform so that the proofs are alike, the artist must, as it were, play one mechanical step against another in order to exploit the medium to the fullest extent; he cannot control the sensitive quality of line, mass, or tone directly or completely in any single one of his operations. A technically perfect etching is distinguishable from a mediocre attempt at a glance; technique and artistic accomplishment are more closely interrelated in etching than in any other graphic medium.

The Plates. Smooth, highly polished plates of zinc or copper $\frac{1}{32}$ inch thick are commonly used. These plates are fairly easy to obtain at artists' supply stores; the specialist in etching, however, usually obtains them from one of the firms which specialize in etchers' or engravers' supplies. Copper is the traditional choice; it is preferred to the somewhat less expensive zinc on account of its superior crystalline texture or grain, its better behaviour throughout the process, and other qualities more subtle, which can be learned from an actual comparison of the two better than from a description.

Zinc plates, however, are adequate when the work is simple and without great delicacy of line or effect—especially when all the lines are of equal value or not too subtly different in value. Steel, a more coarsely grained metal, is sometimes etched; it is chosen for use only in the production of large editions, as in the case of commercial work or book-illustrations, and is incapable of application to fine prints. The earliest etchers employed iron or steel, and overcame its disadvantages to some extent by the exercise of much skilful effort, as well as by a realization of its limitations.

Copperplate etchings and engravings may be, and for large editions always are, faced or electroplated with steel; their resistance to the wear of continual impressions is thereby greatly increased, but some of the distinctive characteristics of copperplate etching may be lost.

Preparation of the Plate. Before applying the ground, the surface of the plate must be made perfectly clean by rubbing it with a soft cloth and one of the volatile solvents and a little whiting. If it is discoloured or tarnished, the application of a mixture of vinegar and salt will usually remove all traces of tarnish. The exposed metal must present a chemically pure surface for the mordant to act upon, and the uniform and complete adhesion of the ground requires a clean surface.

A special holder with a wooden handle and iron jaws is clamped to a corner of the plate, which is then heated and its face rubbed with a ball of wax ground, which is sometimes enclosed in a wrapping of cloth. Learning to apply the ground in a sufficiently uniform coating is a matter of experience; the thickness will depend largely on personal preference. Some grounds are intensely black in colour; others are transparent and require blackening so that the scratches of the needle will be visible. This is accomplished by holding the plate face down and smoking it for a few moments over the flame from a number of wax tapers twisted into a bunch. Some etchers dislike the sooty layer, and dispense with this smoking operation, especially when the

ground they employ is intensely black. I have tried blackening wax-gilsonite grounds by melting the wax and then dissolving in it some oil-soluble aniline black, such as nigrosine. This increases the ground's blackness and opacity.

The requirements for a perfect etching ground are: (1) it must give perfect protection to the plate against any concentration of acid which is likely to be used; (2) it must be of the correct degree of softness so that the needle will cut cleanly through it without any chipping, and expose the copper in clear, sharp lines; (3) it must not be so soft and tender that it will be easily destroyed by accidental handling or that the scraped particles will cling adhesively to the surface of the plate or needle instead of falling away as they should.

The traditional ground is pure beeswax or a mixture of beeswax and asphaltum. This can be and is improved upon by a number of special formulas; prepared grounds sold by dealers in etching supplies serve the purpose well and few etchers find it necessary to make their own. Among the published formulas which have been favourites of various etchers is the following, for Rembrandt's ground (so called), in parts by weight:

Yellow beeswax	2
Mastic resin	2
Asphaltum	1

Another version:

Yellow beeswax	4
Burgundy pitch	1
Common pitch	1
Asphaltum	4

Instructions: melt ingredients together carefully with occasional stirring, adding them in the order named. The molten material is inflammable; make small batches and guard against fire. Some recipes call for white beeswax.

These recipes probably originated in the seventeenth century. Paste grounds, which are applied with a roller, contain the same ingredients thinned down to the proper consistency with turpentine or mineral spirit.

The trouble with most formulas of this nature, especially the old ones, is that the asphaltum, pitch (rosin), and other materials are so unstandardized and vary so much in properties that one always has to do a good deal of adjusting and experimenting before the recipe begins to work as it should. The etcher who makes his own grounds, however, is usually a person who wants to experiment. The properties of the various ingredients are as follows:

Wax. The basic material for the ground; almost good enough alone, but needs the properties of the other ingredients to perfect it. Use as much as possible, which will probably be about half to one-third of the mixture.

Resin (mastic, damar, or rosin). The least acid-resisting of any of the ingredients. Use as sparingly as possible; its function is to set up or harden the ground, to make it less tender, and to raise its melting point.

Asphalts. Highly acid-resisting; the softer varieties will impart flexibility,

and the harder varieties will also contribute strength and resistance to handling. Asphalt will tend to shorten the mixture or lessen the natural sticky adhesiveness of the wax. The hardest and most brittle asphalt is gilsonite, which is like a hard resin; the softer, more elastic kinds among the standardized varieties are Trinidad, Barbados (Manjak), California, and Egyptian asphalts. There are a number of other soft asphalts, both native materials and by-products of oil refineries, which are used industrially in large amounts but which are sometimes difficult to obtain at retail. Asphalt will also colour the ground, but when the ground is spread thinly and evenly over a plate this colouring will be no more than a transparent brownish tinge, and for an intense black coating against which the copper-coloured lines incised in the ground will show up with greater contrast, the plate must be smoked.

Liquid Grounds. The prepared liquid grounds are made by dissolving the solid materials used in the regular grounds in a quick-drying volatile solvent. Ether and chloroform are the traditional solvents in use; the substitution of less dangerous materials from the long list of modern solvents available should be an improvement. The drawback to the use of liquid grounds is their tendency to collect dust particles, which produce weak spots in the coating. The liquid ground is applied by pouring it over the plate; the plate is manipulated so that the ground spreads evenly, then the excess ground is allowed to drain from one corner back into the bottle, an operation which requires some skill.

A recipe for a liquid ground which I have used in experiments is as follows: melt 4 ounces of beeswax; stir in ¼ ounce of powdered nigrosine base, or other oil-soluble aniline black, until dissolved. Pour into 2 ounces of gilsonite which has been melted in a separate can. Remove from stove and thin with a mixture of ½ ounce of kerosene and ½ ounce of mineral spirit poured in slowly with stirring, followed immediately by 8 fluid ounces of toluol. The petroleum solvent is used to start the thinning; if a highly volatile solvent were added first, it would cool the mass too quickly, causing it to solidify in lumps, and the solvent would boil away. (All thinning of varnishes must be done in places with good ventilation and in the complete absence of flames or electric heaters.) This ground can be made more brittle by adding rosin or mastic or by increasing the proportion of gilsonite, and softer by the substitution of a softer asphalt for the gilsonite. A liquid ground can also be made by thinning the molten wax with a ready-made solution of asphalt.

Etching the Plate. The plate prepared for etching is immersed in a bath of mordant, which bites or eats away the metal by chemical action. The commonest receptacle in use is a glass or china tray such as is employed by photographers; a wooden tank or one lined with sheets of lead could be used, if necessary. Acid-resisting porcelain-coated metal is not reliably resistant to the strong concentrations of acids employed in etching mordants.

The traditional mordant is 4 parts concentrated nitric acid and 6 parts water (concentrated C.P. nitric acid is a 68 to 70% solution of HNO_3). Nitrous acid, which is similar in action to nitric acid, is preferred by some

etchers. Further remarks concerning the action of acids in etching will be found under chemistry (pages 302 and 327). Before the acid is poured into the tray for use, it is customary to dip a strip of clean zinc into it for a few moments until it bubbles freely. This ionizes or begins the dissociation of the acid, and puts it in a condition which insures its immediate and steady, continuous action upon the plate. During the reaction between the acid and the copper, the bubbling which occurs should be watched, and if any bubbles start over areas which are supposed to be protected by the ground or resist, the plate must be removed at once, rinsed, dried, and given further protection by applying an acid-proof varnish or resist to these weak points. The defect caused by such accidental solution is known as false biting.

After the plate has been bitten to the correct depth to produce the finest or lightest lines desired in the particular work in hand, it is removed, rinsed, and dried, and the portions which are to remain finely etched are covered with acid-proof resist, applied with a small brush. The plate is then bitten again to produce the next coarser or heavier lines, and so on; experience will determine the depth to which the various kinds of lines should be etched. After the plate has been etched as far as one wishes to go, all traces of varnish or ground are removed with the appropriate solvents, and a trial print is made, whereupon the plate may be re-grounded and any corrections or additions made by further etching. There are several variations of etching procedure, and some etchers will change their techniques according to the particular work in hand.

Iron (ferric) chloride is sometimes used as an ingredient of mordants on the theory that its action tends to be more selectively vertical than that of nitric acid; that is, the lines will be bitten down rather than sideways (see page 385). This action is caused by the rapid deposition of salts on the little walls of the lines, their surfaces being thereby protected from further action of the acid. After a somewhat longer time, the bottom of the etched line also becomes clogged with these salts and the action ceases.

Before a plate is immersed in acid, the back and edges must be coated with a liquid resist or acid-proof paint. The usual material sold for the purpose is a solution of asphaltum in volatile solvent, which dries quickly to a rather brittle finish and which is sufficiently acid resisting to protect the plate from etching solutions. Ordinary shellac varnish into which a little lampblack has been stirred is also used for this purpose. If a wall of wax is built along the edges of the plate, acid can be poured upon the surface alone.

The ebullition caused by the action of nitric acid on a metal is rather violent (perhaps because a double reaction takes place) and tends to disturb the resist coating at its edges; the result is apt to be a coarsening of the lines. For this reason some etchers use the so-called Dutch mordant, a milder solution which appears to have originated about the middle of the nineteenth century; it is made by dissolving $\frac{1}{2}$ ounce of potassium chlorate in 5 fluid ounces of hot water, cooling, and adding $\frac{1}{2}$ ounce of concentrated hydrochloric acid. Dutch mordant has a milder action on copper than the nitric acid solution, and is considered more certain to etch fine lines sharply.

Potassium chlorate should not be used in other mixtures; it is not a safe substance for haphazard experiments. Correct laboratory technique calls for slow, cautious addition of any concentrated acid to water, never water to acid.

The remarks on materials used in an etching ground apply as well to the liquid resists or stopping-out varnishes, except that these varnishes do not have to meet such precise requirements and a larger variety of materials can be used, according to the judgment and experience of the user. It should be remembered that from the viewpoint of solubility, alcohol-soluble coatings, such as shellac, are different from those which dissolve in benzine, toluol, etc., such as the usual asphaltum and wax compounds; when a plate which bears both kinds is to be cleaned for printing, it must be washed with each of these types of solvent separately. The more powerful paint-remover solvents, such as acetone, will usually remove both kinds of coatings. Waxes and waxy materials are used to plasticize these acid-resisting varnishes, that is, to render them less brittle, so that when they are scratched through with the etching needle, the line will be clean and sharp. If, for example, the highly acid-resisting varnish made of pure gilsonite and solvent were scratched with a needle, the edges of the scratched varnish would chip away in a rough and erratic manner. An acid-proof stopping-out varnish or resist in the thin layers in which it is applied in etching, is usually just about adequately resistant to the mordant to accomplish its purpose, and cannot always be depended upon to resist stronger concentrations of acid or to withstand immersion in acid for extended periods of time.

An important consideration in etching, as in any other chemical reaction, is the temperature. In order to secure uniform, controlled results, and to be able to rely upon former experience in timing the etching periods, careful workers will use a thermometer. Normal room temperature, about 65° F., is standard; as is usual in most chemical reactions, heat accelerates and cold retards the action.

Soft-Ground Etching. Soft grounds are made of the same materials as the regular grounds, plus 50% of tallow. They need not contain any blackening material. When a plate coated with soft ground is covered with a sheet of paper and then drawn upon with a pencil, the ground under the pencil pressure will adhere to the sheet, and when the paper is lifted away, the ground under the lines of the drawing will come away with it. Such a plate differs from one made with a needle in that the line can be made to vary in strength through width instead of through depth of biting, and the plate may be bitten without so much use of stopping-out operations. The character of the line is more or less grainy, like that of a crayon line, depending upon the texture of the paper.

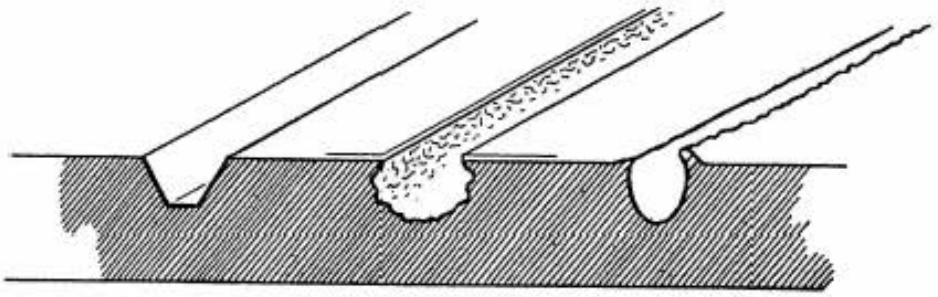
Dry Point. Technically, the dry point occupies a position between the etching and the engraving; the process is simple, direct, and autographic.

A copper plate, the same kind as is used for etching, is blackened with the soot of burning wax tapers, and the drawing is scratched directly upon its surface with a needle whose point must be sharp rather than rounded. Sometimes a diamond point is used. Gramophone needles are popular for use in

etching; they have rounded points. The plate is then cleaned, inked, and printed. Dry point and etching are often used in the same plate.

As illustrated in the drawing below, the natural dry-point line has a characteristic soft effect from the ink deposited by the burr or raised edge. This burr is delicate and will not hold up under any severe treatment or withstand the wearing pressure of very large editions; when required, it can be removed entirely by using a scraper, the same triangular-edged instrument used in copperplate engraving. A sharper line will then be produced. Dry point is considered best adapted for direct, spontaneous work, and its effects are less deep and varied than those of etching.

Aquatint. An aquatint is an etching in mass instead of in line, and is made possible by the application of a special ground which contains powdered rosin of various degrees of fineness. The acid surrounds these particles of rosin and bites through to the metal at their edges, thereby creating a grainy effect; the irregularities of the grains prevent the texture from appearing mechani-



Engraved *Etched* *Drypoint*

cal. There is no technical or artistic objection to combining line etching or dry point with aquatint; almost all aquatints require line work and rely upon it for many of their results. Such prints are usually called aquatints, even though the major part of the work is line. A great number of variations and modifications are in general use to produce a number of variously grained effects.

Aquatint is practised only by experienced etchers who have an inclination to experiment with materials and develop their own methods and manipulations; few artists are content to follow any set or standard procedures after becoming interested in the technique. The principal methods may be outlined as follows:

The plate is grounded by covering it with a layer of powdered rosin. This is accomplished by dusting the rosin on through a cloth bag, by sifting it through sieves from a height of several feet, or by shaking it around in a specially made box, then inserting the plate and allowing the powder to settle upon it. The plate is then warmed on an electric or gas heater for a few moments, which fuses the particles and causes them to form a hard ground of granular texture. If this were immersed in acid, the result would be a plate which would print a solid area of granular tone; the acid bites through the points unprotected or insufficiently protected by the fused particles of rosin,

which is a semi-acid-proof material whose resistance can be controlled by varying the thickness of film and the duration of etching.

Another method of graining a ground is to run a plate coated with regular etching ground through a press together with pieces of sandpaper, the operation being repeated as many times as necessary.

Before the biting, the picture is made by painting upon the grounded plate with regular stopping-out or resist varnish, and gradations of tone are produced by repeated biting and stopping-out.

Many varied textures are obtained by such manipulations as producing white lines by painting with resist varnish before applying the rosin, or by drawing on the plate with grease pencils which are acid-resisting.

Printing Etchings. In etching, the printing is so much a part of the complete process that the etcher usually prints his own plates. After he has succeeded in printing a perfect trial proof, he may turn the rest of the edition over to an expert printer, but the number of such experts is so limited and the effects are so dependent upon the artist's personal work, that this is seldom done. The planning of the composition, the original strokes of the drawing, and the biting of the lines are all carried out with the final printing in view.

The plate is inked by working the ink into the etched lines thoroughly with a dauber, in all directions. When the lines have been filled in with ink to the satisfaction of the printer, the surplus ink is wiped from the flat surface of the plate. Theoretically, a technically perfect etching should be wiped absolutely clean, and the final proof should consist of inked lines clearly printed on clean paper, without smudging or other effects caused by ink remaining on the flat areas of the plate. Actually, tradition and taste allow for considerable latitude in this connection, and the artist ordinarily obtains a number of different effects by manipulating the process of wiping the plate. However, over-dependence upon accidental inking effects is usually condemned.

The inks used in etching differ from ordinary printing inks according to obvious differences in function; they are, however, basically similar to the others in that they are black or coloured pigments ground into thickened linseed oil by roller mills. A number of satisfactory inks are on the market; the principal variation an etcher will need is in tone or colour. After a little experiment he will soon discover the make or type of ink that best suits his particular purposes, and will not usually change unless he changes the other details of his procedure. Etchings are ordinarily printed in normal, true black; sometimes they tend toward the brownish, or are even a definite brown. Etchings in other colours are rarely made. Multicoloured etchings made with single impressions by such procedures as inking various parts of a single plate by hand with inks of various colours, do not conform to artistic requirements and are not colour-etchings but coloured etchings. Colour-etchings would be made in the same way as other colour prints, by printing each colour plate separately.

Engraving on Copper and Steel

Successful engraving requires a well-developed personal skill in manipulating the gravers, or burins. The gravers are tempered steel instruments with oblique points and wooden or cork-covered handles which are designed to fit into the palm of the hand. The steel is grasped with the thumb and fingers near its point, and the edge of the thumb must press against and glide along the surface of the plate in order to guide the point in a free and sensitive manner and to prevent it from becoming buried in the metal. The plate rests upon a circular leather pad, and is held by the engraver's left hand in such a way that it can be tilted and revolved, these motions being coordinated with the movements of the graver and used equally, especially in engraving curved lines. When the work is finished, the burr which the graver raises in occasional and varied places must be removed by rubbing with a few strokes of the scraper held flat, after which the plate is ready for trial impressions. The scraper is a triangular blade with sharp edges, which removes the burr without injuring the plate. Printing is done as in the case of etchings, except that after the plates are inked they are wiped very clean; the printing of an engraving is an altogether mechanical operation.

Woodcuts and Wood Engravings

The term woodcut is correctly applied to work done by cutting out the surface of a smooth plank of hardwood with a knife, aided by the use of a few V and U gouges for more delicate lines. Seasoned planks of apple, pear, cherry, beech, and sycamore of type-high thickness (·918 inch) are used.

The term wood engraving is applied to work done on blocks made by sawing the wood so that the surface is the end of the grain; and instead of knives and gouges, gravers are used—the same tools which are employed in metal-plate engraving. Carefully prepared blocks of boxwood are sold for this purpose, as well as pear blocks, which are considered second choice but are adequate for most uses. Compared with woodcutting, wood engraving is essentially a white-line-on-black-background technique; that is, one works from black to white to a greater extent than when cutting on a plank where larger areas of white are incised and the black and white masses are manipulated more equally. The earliest masters of the woodcut produced work of strength combined with delicacy of line, but the technique is at present considered more adaptable to robust, free work, while the wood-engraving technique is preferred for work which requires more refinement or accuracy of line. The modern print maker will more often than not combine both techniques on a single block.

At the peak of its development during the nineteenth century, wood engraving was used principally as a means of reproducing drawings and photographs, and its characteristic qualities were subordinated to the production of imitative effects. Its use as a purely artistic technique is modern.

Minor Graphic Processes

Under this heading may be grouped several techniques which for various reasons seldom attain the dignity of seriously developed art media. Their limitations or qualities may be more suited to light or decorative work than to significant or 'monumental' art, their processes may not be amenable to precise control, or their effects may be lacking in appeal to discriminating taste—usually for sound reasons.

Linoleum Cuts

The limitations and restrictions imposed upon an artistic medium by certain intractable materials are overcome by a competent mastery of the technique; exploitation of all the medium's desirable qualities then becomes possible. As a result of this, a certain element enters into the work which enhances it, according to most artistic doctrines. In such traditional techniques, the substitution of newer materials which lack some of the properties of the old materials, and which do not present such difficulties, will result in effects which lack this element; it is for this reason that the easily cut linoleum is less esteemed by artists than is wood. The linoleum will not take very delicate or subtle cutting, and its characteristic effect is composed of rather blocky or poster-like forms. However, the technique enjoys a certain popularity among artists for the production of less important and more casual work.

For the most part, the remarks on woodcutting apply to linoleum cutting; lighter-weight tools made for the purpose are now sold in place of the regulation wood-carving knives and gouges, but they are less satisfactory. Linoleum is composed of burlap coated with a heavy layer of linoxyn, which is made of polymerized oil mixed with ground cork and pigments. The best grade is known as battleship linoleum, and is usually brown or grey. If desired, it may be mounted or purchased ready-mounted on wooden blocks so that the cut is type-high in order that it may be taken by a printing press. Small, inexpensive presses may be purchased or improvised; when regular printing ink is used the printing presents few difficulties. Fairly satisfactory (but not perfect) impressions may be made even by such makeshift procedures as placing the inked linoleum cut and the paper between boards or between the leaves of magazines, and bearing down on them heavily with one foot.

The Monotype

The monotype occupies a place between the graphic arts and painting, the proofs being unique and not precisely accurate multiple reproductions. Because these proofs are indirectly produced and printed on paper, and because usually an artist turns out an edition of several copies or versions of the same subject, monotypes are generally classed among the graphic arts. They usually display accidental effects; ordinarily no effort is made to pre-

vent this, and only approximate results are expected in the making of duplicates.

The usual monotype is a painting in any convenient medium which does not dry too rapidly—ordinary oil paint, printing inks, or even aqueous paint—done on a metal plate or a sheet of plate glass, either freely or following a transferred outline drawing. A sheet of paper is laid over the painting, held firmly with the fingers of one hand so that there is no lateral movement, and rubbed with any convenient implement to effect the transfer of the painting. Many variations suggest themselves to artists, and there are few standard methods.

Silk-Screen Printing (Serigraphy)

I have placed this process among the minor techniques, not for any of the reasons noted above, but because it is of such recent development that no widespread use by large numbers of artists and no standardization of materials have been possible as yet. The method is simple in principle and execution; it is basically a stencil process, where the designs are placed upon a piece of fine-mesh silk tacked to a wooden frame, various film-forming materials being used as resists. The specially made colour in the correct semi-liquid consistency is poured into the frame, the frame is placed in contact with the surface to be printed upon, and the colour is scraped over the stencil with a rubber squeegee, thus being deposited upon the paper or other ground through the meshes of the uncoated areas of the silk. The wooden frame upon which the silk is stretched is made about two inches deep so that it forms a box (with the silk constituting the bottom) within which the paint can be conveniently manipulated with the squeegee. Although successful monochrome prints can be made with one impression, almost all of the development work on silk-screen printing as a fine-arts medium has been done with the aim of producing colour prints in a full, unlimited range.

In the past, artists have taken up many stencil processes for the multiple production of their works, but because of technical limitations none of these have developed beyond the status of minor techniques or mechanical reproductive processes. The silk-screen techniques, however, present all the major attributes of a true graphic-art medium, and if their development proceeds in the future as it has up to the present, they should soon attain a permanent place among the accepted graphic-art media. The name serigraph has been proposed as a designation for an artist-made silk-screen print in order to distinguish it from silk-screen work that has been executed on an industrial or purely reproductive basis. The prints may be described as resembling gouache paintings, with some colour-lithograph qualities, specific effects varying according to the technique or style of the artist.

The origin of the silk-screen process has been explained in various ways, but its development as an art medium stems directly from the advances and standardizations made in its industrial use during the past two decades. An early adaptation of the process was the decoration of textiles in loose, free-

hand patterns, the resist portion of the stencil being painted with an opaque oil paint or lacquer, and starch- or gum-thickened solutions of water dyes being used. With the introduction of Profilm,* a patented material which replaced the liquid resist, the process became more adaptable to use by individuals and decorating departments of various establishments, as well as by workshops which specialized in silk-screen printing for various purposes.

Today these activities have assumed the proportions of an important industry served by a number of dealers in supplies and equipment. Profilm consists of a thin film of coloured cellulosic or synthetic material of the type that is readily dissolved by the various lacquer solvents, mounted on a sheet of glassine paper with rubber cement, the whole transparent enough so that drawings can be traced through it. Stencils are cut from this material with a small, very keen stencil knife, care being taken to cut through the film but not through the paper. The cut-out areas are removed, and the finished stencil is made to adhere to the frame-stretched silk by placing it face down upon it and applying lacquer solvent to the back of the silk, whereupon the film will partially dissolve; when it has dried it will adhere. The paper backing is then peeled off. After the margins around the stencil have been coated with a lacquer resist and the edges protected on both sides with gummed tape or similar material in order to make a tight seal between the silk and the frame, the stencil is ready to print. The tape as well as the wooden frame should be shellacked.

This process is applicable to work of some delicacy, such as fine lettering, simple designs, posters, etc., and may be used alone for some types of artistic work, but for the completely controlled intricate printing areas demanded by free artistic drawing, modifications must be employed. The film process may be used as a basis for or in combination with other methods if desired.

Silk-screen printing was first publicly sponsored as a fine-arts medium by the New York WPA Art Project, which organized a producing unit for silk-screen prints as a division of its graphic-arts department. The development of the process for artists' use is due largely to the work of Anthony Velonis, who has made considerable progress in establishing and standardizing techniques and in furthering their adoption by artists. The following outline is based largely upon his practice and recommendations.

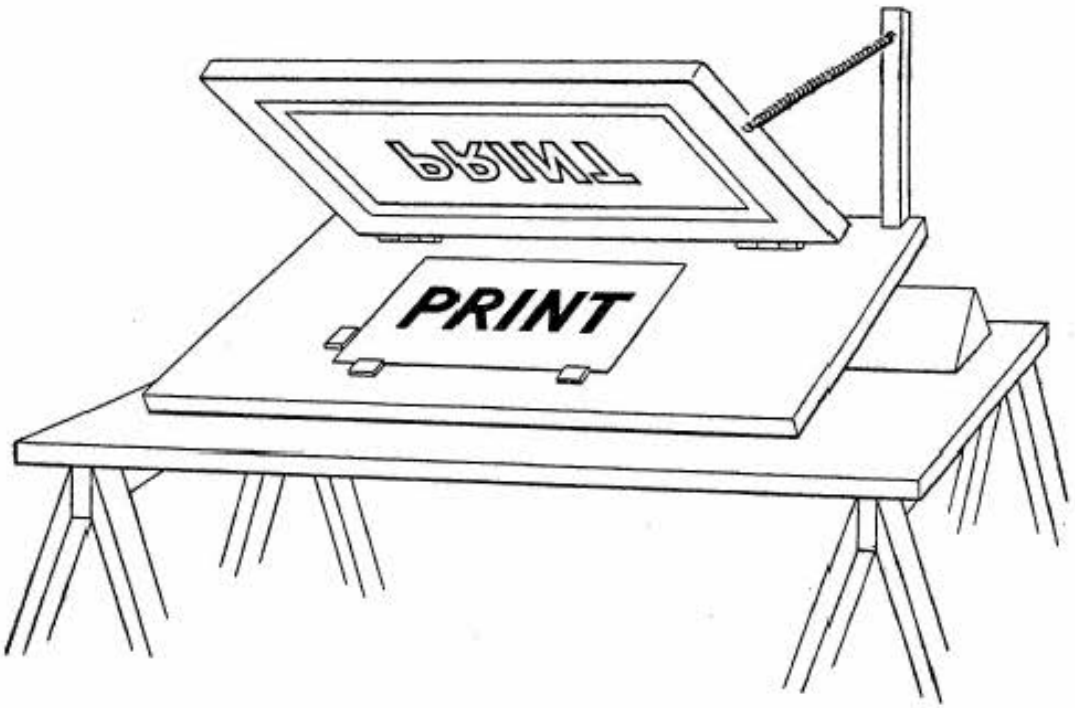
The frames are sturdily built of good timber about 2×2 inches, and brass hinges with removable pins are fastened to one of the long edges (referred to here as the back edge) so that the frames can be hinged to the 'table' (a plywood board somewhat larger than the screen) and interchanged. The silk used is sold for the purpose in two weaves, bolting cloth and taffeta or stencil weave, in many degrees of mesh, from 00 (coarsest) to 18. Numbers 12 and 14 are average. The silk is tightly stretched by tacking it on the frame or by using a special clamp frame, after which the margins and edges are treated as previously described. The frame must be large enough so that a margin can be left around the drawing for manipulation of the paint.

Printing operations are facilitated if a screen-door spring is attached to an

* Selectasine Silk Screens Ltd., 11 Southampton Row, W.C.1.

upright at the back edge of the table, and hooked to the side of the frame near the front edge so that the frame is held up some inches above the table and is in contact with the paper only while the print is being made. Registers similar to those used when paper is placed in a printing press, are made by gluing three small squares of thick cardboard or celluloid to the table as guides for holding the paper in place, two along the front edge and one at the left near the front.

Before the printing operations are started, the 'table' is propped up at an angle on the actual table or horses upon which it is used, by placing a length of wood under its rear edge.



Tusche-Washout Method. Fasten the original drawing or painting to the table with drawing pins or Scotch tape in such a manner that after it is removed it can be replaced again in the identical spot. Let the prepared and taped screen down over it and with a pencil trace outlines or guide points of the colour area to be printed.

Paint the picture directly upon the right side or top of the silk with lithographic tusche (see page 381), using various brushes and manipulations, according to the effect desired. Allow to dry. Prop the screen at the corners so that it is level, right side up, and coat entire silk, including the drawing, with glue applied evenly and neatly with a squeegee. A good mixture is Lepage's liquid glue 50, water 40, vinegar 6, glycerin 2. When this is dry, repeat the glue coating and allow to dry again. Turn the screen over, and impregnate the tusche areas with mineral spirit or kerosene. Place the screen on newspapers, right side up, and apply more of the solvent liberally, spreading and rubbing gently with a neatly folded rag. Remove the top sheet of newspaper, add more solvent, and continue rubbing until the tusche is washed out. The

glue over the tusche will flake away; use a nail brush to remove obstinate spots if any remain. When the printing areas are entirely clean and clear, the design will be surrounded by a glue resist, the silk is ready for printing, and the frame is replaced in the table hinges.

A wide variation in textural results can be achieved by drawing on the screen with a No. 2 lithograph crayon. Sketch in the printing areas with a lead pencil as described above, then place the screen over any desired textured material such as sandpaper, a file, engravers' Ben Day plate, Ross board, egg-shell board, etc., and work with the crayon over the areas to be printed. Apply the glue resist and wash out the crayon as in the regular tusche method. Crayons may be used either alone or in combination with tusche or other methods.

Simple Cut-In Method. Instead of producing the printing area by direct or positive working, one may outline it in a negative technique, that is, by painting the silk around the drawing with glue or lacquer and leaving the printing area open. This method is rather difficult to apply to designs of any great finesse, but it is very useful for free, loose work and can be used to produce a good deal of variety.

Glue-Shellac Method. Squeegee the glue solution over the entire screen; when it is dry, touch up any pinholes with a brush. If there are many, a second very thin coat of glue may be used. The screen will be transparent enough for the drawing to be traced through it. Using a brush and black shellac or black lacquer, cut in the areas which are not to be printed. This can be done much more effectively here than in the preceding method because of the good surface created by the glue.

Touch up errors, pinholes, or thin spots with additional shellac or lacquer. When the screen is dry, prop up off the table in a perfectly level position, right side up, and wash the glue out of the printing area by going over it very carefully with a clean soft rag dipped in water. Wring out the rag, pick up excess water, and repeat; the glue dissolves only gradually. Do not flood the screen with too much water. Continue applications until the printing area is clear, then wipe with a dry cloth. Work only on the top side of the screen. This kind of stencil prints fairly sharp outlines and holds up well for long runs, but is not often used by artists.

Other Methods. A number of less effective methods are in use; they are applicable principally to simple or crude designs. A reverse process, that is, one using a water-insoluble resist and aqueous paint, might have desirable properties, except that a water paint has a tendency to cause the silk fibres to warp or expand and thus throw the work out of register somewhat. The most developed aqueous paint method employs Profilm, applied by ironing. Another one is a reverse of the method described with tusche, in which the printing area is painted with a water-soluble paint or glue, and when this is dry the entire screen is coated with imitation shellac (real shellac being too difficult to remove from silk screens). The glue or paint is then washed out of the screen with water from both sides, and the finished stencil is dried and printed with an aqueous paint. Despite much effort, a perfect water paint

has not been developed; the most successful have been made of starch paste, honey, glycerin, and preservative. Metal screens may be had in very fine meshes and are not affected by aqueous mediums, but they do not work out well in practice; they are expensive, and the slight accidental contacts involved in normal handling, which do no harm to a silk screen because of its elasticity, will ruin a metal screen by causing permanent dents.

Multicolour Prints. The methods for producing multicolour prints are in general the same as those used in any graphic colour-printing process, except that the serigraph has the advantage that a key screen which will print the complete design is in the great majority of pictures unnecessary or undesirable. The number of colours and textural effects which may be employed is unlimited, and colour applications may be continued indefinitely, the same as in a painting. Transparent and opaque areas may be manipulated in many ways, and there is no appreciable expense attached to the use of a dozen or more separate screen impressions if desired. The paint is carefully rinsed out of the screen at the end of each run; the same stencil may be reprinted in another colour or partly blocked out and reprinted in part; when the resist is no longer required, it is carefully removed by washing it with the appropriate solvent, and the screen is ready to receive another drawing. Two silk screens will be sufficient for the average artist's use. Depending upon the size of the editions and the number of colour impressions used, the silk will eventually wear out and require replacement.

Equipment. All the equipment and materials for the process may be purchased from the regular dealers in silk-screen supplies* and from some artists' supply stores, at prices which are very low in comparison with the cost of the usual graphic-printing equipment; the mechanical items can be made by simple carpentry if necessary.

The material sold as transparent base is a vaseline-like paste of alumina hydrate ground in the same vehicle as the pigments with which it is intended to be mixed to produce transparent effects. Its use is an important factor in the production of good prints. It may be mixed with regular artists' oil colours, if desired. The mediums are formulated to work well in the process and to dry very rapidly—needing from a half-hour to overnight.

Further Improvements. The paints used at present are industrial products and are not formulated to conform to artists' criteria of permanance. Although it has been pointed out that they are of the same quality as printing inks, it must be remembered that printing inks are applied in thin layers which act as mere stains on special papers, while serigraphy deposits a real paint film. The paint-film character, whether in thin glazes or opaque layers,

* Though there is considerable activity in commercial silk-screen printing in Britain, not enough artists have interested themselves in the process to encourage a single retail dealer in silk-screen supplies or to encourage the Artist's Colourman to stock specialised materials. The organdie is in short supply and preference is given not only to known trade customers but to orders for larger quantities than the private artist would normally require. It is suggested that artists interested in the process approach one of the several silk-screen printers listed in the Trade Directory, who may put him in touch with an amenable source of supply or consent themselves to furnish him with the small quantities he would require.

is one of the outstanding qualities of the finished prints and contributes largely to their optical and artistic success. In this connection, it must be remembered that any paint layer is subject to a number of eventual defects if not carefully formulated. Simple tests would indicate whether or not the pigments and mediums used in the industrial products meet artists' requirements as to permanence. The composition of the mediums used in the present commercial paints is unknown; the colours bear fantastic designations, and the earth pigments are missing from the lists. There is no reason why mediums and colours cannot be formulated to meet artists' requirements.

Some Notes on Sculptors' Materials

These notes were assembled for the purpose of beginning a study of the properties of various materials used by sculptors, the literature of which is scant.

Modelling Materials

Modelling Wax. The simplest modelling material is a prepared non-hardening plastic substance universally sold for the purpose. The traditional high-quality material, which originated in Italy, is a mixture of tallow, sulphur, and a special type of clay. It lasts indefinitely and can be used over and over again, so long as it is kept clean. It has just the proper mechanical or plastic properties, and is customarily of a green-grey colour. Modelling waxes are sold under a number of trade-marked names, such as Plasticine, etc. The cheaper grades are imitations of the original material; they generally hold their shape well and are adequate for most purposes, but are always inferior to the best or professional grade. Their composition varies; they are usually made of clay, other inert filler, and colouring matter, combined with various petroleum or paraffin greases and oils.

Clay. Clay is a native earth consisting largely of kaolin combined with silica. Many varieties of clay occur in nature, and various small percentages of impurities are the chief causes of their distinctive properties; for every use there is a best-suited variety. When wet, all clays are plastic to some degree and can be modelled; if the moulded objects are fired in a kiln or furnace at high temperatures they become hard and rock-like, retaining their shapes. Some of the most plastic modelling clays, however, are not well suited to ceramic uses. The varying degree of plasticity in clays has been attributed to a number of chemical or physical causes, and the question is still greatly disputed.

Sculptors' clay is selected for plasticity and moisture-holding properties at a sacrifice of other properties which are important in potters' clay. Sculptors' clay is used only to make models which are to be cast in some other material soon after they are completed. Useful varieties occur in all parts of the world.

Sculptors' clay will last indefinitely in its original powder state or if kept in a wet or moist condition; when it is much kneaded and aged in the moist

state it improves in plasticity. If wet clay is allowed to set and harden, a considerable amount of reworking, usually by mechanical means, is required to bring it back to its smooth plastic form; on account of its low cost and the labour involved in reworking it, hardened plastic clay is ordinarily discarded. When a piece of sculpture is being moulded in clay, it must not be allowed to dry out, because of the cracking and shrinkage which would ensue; it must therefore be moistened by a liberal spraying or whisking of water every twelve to twenty-four hours, and in the average climate is best wrapped in damp cloths and then covered up to minimize evaporation of moisture during periods when the work is set aside. This is most easily accomplished by constructing a light, movable framework covered with oilcloth with the coated side in. Wet clay is stored in a pail or tub, it is covered with wet cloths, and the container is closed with a tight-fitting lid.

Terra cotta is a ceramic clay usually but not always containing iron oxide, which imparts a characteristic reddish colour to it. Pale, whitish varieties are also in use, as well as those of intermediate colours which are obtained by mixing clays and by adding small amounts of iron oxide or other colouring ingredients; but the traditional terra-cotta colour is a pale tile red, such as would result from mixing burnt sienna, white, and a little red oxide. Sculpture modelled or cast in this material is directly fired in kilns and made permanent and durable. Its surface may sometimes be coloured, glazed, or enamelled with various ceramic materials before firing.

Plaster of Paris is described on page 324.

Stones

The use of a fine snow-white or creamy-white native marble of smooth crystalline structure by the ancient Greeks established this material as a traditional standard for artistic sculpture and architecture in Europe. The Romans perpetuated this tradition by using similar white marbles; they also carved many other native stones. In England and America the standard marble, and for many years in the past the only acceptable standard sculptors' medium, has been the pure white or slightly toned Carrara marble from Italy. Sculptors, however, have always employed an almost unlimited number of stones of various colours, textures, and degrees of hardness, durability, and ease of manipulation. Each one is selected not only for its technical fitness for the work in hand but also for its appropriateness to the nature of the work.

All stones are perfectly durable and permanent when preserved under normal indoor conditions, but for outdoor use they vary greatly. The conditions which outdoor sculpture have to withstand are both chemical and mechanical, and include wearing or abrasion and destruction by water, frost, and the action of acid or acid-forming gases in the atmosphere. Few stones will withstand great heat, as in the case of fires. I do not know of any researches into the durability of artistic stone sculpture under exposure to weathering, but from the studies which have been made of different kinds of

are not reliably so; but in order for most of them to enter into reactions, the proper conditions must be present. When two stable, inert pigments containing elements which are theoretically capable of reacting on one another, are mixed, it is often the case that on account of the stable, inert character of the pigments there is no danger of such actions taking place, because the conditions necessary to the reaction are absent. On the other hand, certain otherwise inert materials may be extremely sensitive to such mutual action. No indiscriminate rule may therefore be made, but the characteristics of each pigment or other material must be learned.

The carbonates and the sulphides of metals are all extremely sensitive to action by mineral acids; the oxides are inert substances more often than not. The salts of many metals and groups of metals have general properties in common, such as colour. Most crystalline salts of nickel are green; those of copper, blue; and those of cobalt are rose-coloured, changing to blue when they are made anhydrous. Chromium was named for its varied colours; all of the compounds of this metal are highly coloured. Zinc and aluminium compounds are white or colourless; very slight traces of iron impart a yellowish colour to a solution or composition. These general remarks on colour do not apply to compounds which contain more than one metallic element.

Sodium and potassium are two very similar elements, whose compounds are closely allied. From the viewpoint of technical uses, a broad general statement is that a potassium compound is more active and will give somewhat better results than its analogous sodium compound, but the less expensive and more available sodium compound is usually adequate for the purpose. There are occasional exceptions to this statement; sometimes one compound is entirely unsuited to a reaction which calls for the other, and sometimes the two will give distinctly different results.

Valence. Atoms of an element may be graphically imagined to have a certain number of arms or hooks by which they become linked to other atoms to form compounds. The number of such hooks an element has, is called its valence; for example, it will be seen in the formulas in the following pages that oxygen has a valence of 2, hydrogen 1, carbon 4, and the benzene radical a valence of 6. (A radical is a molecular group of two or more elements which often hangs together and acts like a single element during a reaction; the hydroxyl (OH), carbonate (CO_3), sulphate (SO_4), and ammonium (NH_4) radicals are familiar examples.) It should be clear that these arms, links, bonds, etc., are theoretical descriptions of behaviour, not tangible items. Valence can be more scientifically defined as the number of hydrogen or chlorine atoms with which an atom of the element in question will combine, the valence of hydrogen and chlorine being 1.

Some elements are polyvalent, that is, they have the ability to form perfectly normal and saturated compounds in more than one proportion; for example, iron, as in the oxides previously mentioned, has a valence of 2 and 3, depending upon the conditions under which the combination occurred.

Nomenclature. The names of the elements were derived from a number of sources. The elements which were known in very early times or whose pro-

minent compounds were known have names which come from basic roots of the various languages; those more recently isolated were named (in Latin or Greek form) for their properties, their compounds or sources, or in honour of their discoverer or the land where they were discovered.

Binary compounds (those which consist of two elements) customarily take the name of the more definitely metallic or electrically positive element, followed by the name of the more negative element with the ending *ide*. Sodium sulphide is a compound of sodium and sulphur; zinc oxide, of zinc and oxygen. Some elements may function in both ways. For example, chromium occurs in the usual oxides and salts (chromium oxide, etc.); it also exists in a series of acid compounds—chromic acid and its salts, which are called chromates.

A substance that can be identified as the salt of a normal acid is named after the metallic constituent followed by the acid name ending in *ate*. Sodium sulphate (Na_2SO_4), for example, is the sodium salt of sulphuric acid (H_2SO_4); it can be made by the reaction of sulphuric acid and a sodium compound. Sometimes the significant elements of two acids are identical in kind but different in number. The salt corresponding to the acid with fewer atoms to the molecule takes the ending *ite*; sodium sulphite (Na_2SO_3), for example, is the sodium salt of sulphurous acid (H_2SO_3). The endings *ic* and *ous* are employed to designate numerical variations in an acid or oxide; the molecules of the *ous* compounds have fewer atoms or a smaller proportion of oxygen than do those of the *ic* compounds.

Generally the acids, and most of the salts, which end in *ous* are the more unstable, and those which do not contain their maximum complement of atoms are called unsaturated. Some of them will take up additional atoms with avidity; others will freely disintegrate or give up their atoms. This is not to say that the *ous* compounds are always unstable or unreliable as regards permanence; for instance, the ferrous (iron) oxides are as thoroughly inert and permanent pigments as we may desire, and would require the most drastically severe chemical conditions or extremely high temperatures to be altered.

Further designations are given to compounds for other reasons, which are often self-evident. The prefix *hyper* is applied to the numerically highest in a series of compounds; the prefix *hypo* indicates the lowest. The prefix *per*, as in peroxide, perchloride, etc., denotes the higher of two compounds—usually the higher in valence as distinguished from the first, lowest, or mono form. The prefix *proto* is obsolete; it referred to this lower form. *Thio* means sulphur-bearing.

Other prefixes referring to numerical variations are *di* (or *bi*), *tri*, *tetra*, *sesqui*, etc. *Meta*, *ortho*, and *para* refer to variations in arrangement.

Oxidation. The chemical combination of a substance with oxygen to form an oxide, is the commonest reaction in nature. When a substance burns it oxidizes; combustion is defined as rapid oxidation with the accompaniment of heat and flame. An example of slow oxidation is the rusting of iron. Iron oxide for use as a pigment, however, is made by the calcination (roasting) of

an iron salt, where by close control of the process a number of shades and hues can be produced.

Some oxides may be reconverted to the original metal or from the *ic* to the *ous* form by reduction, which may be considered a reverse process. In chemistry, the terms oxidation and reduction are sometimes applied to reactions not involving oxygen, where a substance is changed from a numerically higher atomic form to a lower, or vice versa.

Polymerization. Polymerization occurs occasionally in artists' materials and processes; it is a reaction where nothing enters into or leaves a compound but where the change is internal and the atoms become rearranged, condensed, or joined in a different pattern, altering the properties of the substance as definitely as they are altered in any other chemical reaction. The term is rather loosely used in this book and in most other technical accounts, to describe changes which may be complex reactions involving other considerations at the same time.

Catalysis. A catalyst is a substance which assists in the production or acceleration of a chemical reaction without itself entering into the reaction.

Hydration. Some compounds, especially oxides, exist in a form where the hydroxyl radical (OH) is combined with them; they are not pure or simple hydroxides, but 'hydrated oxides'. Such materials can be reduced to the pure oxide form by subjecting them to heat. This process involves a chemical change and is not to be considered a mere driving off of water; the temperature required is usually quite high.

Water of Crystallization. Many salts occur in more than one structural form in combination with water. Thus the transparent blue crystals of copper sulphate, although perfectly dry to the touch, contain 7 molecules of water to each molecule of the salt, and the chemical formula is written $CuSO_4.7H_2O$. If the crystals are heated, the water is driven off, and anhydrous $CuSO_4$ (a white powder) is the result.

Hydrolysis. This is a chemical reaction caused by the action of water; it results in the decomposition of a salt to produce a new substance.

Solubility. Solid substances are soluble or insoluble in water and other liquids to varying degrees; tables are published in chemical handbooks, listing the solubilities of all chemical compounds. With few exceptions, heat increases and cold diminishes the solvent power of a liquid. A solution which contains as much of the solid material as it will hold at normal room temperature, so that further addition would not go into solution but would remain in the liquid as undissolved matter, is called a saturated solution. When a liquid is heated so that it will dissolve more than this normal amount of solid, and is then cooled to room temperature, the additional amount of solid will fall out or crystallize, and the resulting liquid will be a saturated solution.

Absorption and Discharge of Moisture. Some crystalline substances have the property of losing their water of crystallization when exposed to dry air; sal soda is an example. This property is called *efflorescence.* Others, notably calcium chloride, alcohol, and lye, will absorb moisture from the air. Such materials are called *hygroscopic*; and if the affinity for water is so great that

the substance becomes spontaneously dissolved or wet, the property is termed *deliquescence*. The same terms are used to denote the same properties in non-crystalline materials.

Allotropic Forms. When an element exists in more than one form, as regards superficial physical or structural properties, these variations are called allotropes. The various forms of carbon, e.g., lampblack, diamond, graphite, etc., are familiar examples.

Symbols. In the early days of chemistry the cabalistic symbols of the alchemists which were employed ceremonially (as much to mystify the layman as for any other reason) survived for a while, as a sort of shorthand or convenient method of representation. With the scientific development of chemistry, a universal system of shorthand designations for the various elements and their reactions came into use.

An atom is represented by the initial letter of the element. Where more than one element has the same initial, another significant letter is added in lower case; thus, C is carbon, Cl is chlorine, Cd is cadmium.

Chemical Formulas and Equations. A chemical formula expresses in concise form the number, proportion, kind, and arrangement of atoms in one molecule of a substance. A chemical equation expresses the reaction which takes place between two or more substances and the resulting redistribution of the atoms in mathematical balance, according to atomic theory and other laws. An example of a chemical equation, that involved in etching, is:

$$\underset{\text{3 parts of copper}}{3Cu} + \underset{\text{8 parts of nitric acid}}{8HNO_3} \rightarrow \underset{\text{3 parts of copper nitrate}}{3Cu(NO_3)_2} + \underset{\text{2 parts of nitric oxide}}{2NO} + \underset{\text{4 parts of water}}{4H_2O}$$

The coefficients, or large numbers preceding the symbols, refer to the number of molecules or parts by weight of each substance which will complete the reaction according to the law of definite proportions; they are like the figures in a recipe. The small sub-numbers refer to the number of atoms of the element which combine to form a molecule of the particular substance; these are fixed and invariable for each substance. The group of symbols enclosed in brackets is the nitrate radical previously mentioned. Its valence is 1; the valence of copper is 2; therefore, two of these nitrate groups are combined with one atom of copper, and the brackets in this particular case indicate that the subscript 2—the small figure below the line of the letters—qualifies the entire group.

If the numbers of atoms of each element, as indicated by both the coefficients and the subscripts, are added, they will be seen to check, or balance, on each side of the equation. For instance, there are 24 atoms of oxygen indicated for the nitric acid, and the total on the right-hand side of the equation is also 24: 18 in the copper nitrate, 2 in the nitric oxide, and 4 in the water. Matter is indestructible and all the ingredients which enter into the reaction must be accounted for.

In the actual etching process, considerable water is also present, but although it makes possible the particular reaction, it does not enter into it, and so is ignored in the equation. The copper nitrate dissolves in the water as

soon as it is formed, the NO passes off as a brown gas, and the copper is apparently eaten away. The colour of copper nitrate is green; if we saved the greenish solution instead of pouring it out, and boiled off the superfluous water, we could obtain crystals of copper nitrate, which in turn could be reduced to pure metallic copper. Without the water, a somewhat different reaction would occur.

As a matter of fact, the above reaction is a rather complex one. The left-hand group shows the beginning, the right-hand group shows the result, but the reaction actually occurs in two stages, and should be represented by two formulas, were we interested in following up its theoretical aspect rather than its practical application.

Organic Chemistry

Compounds of the element carbon are so numerous and arranged into groups and series of such complexity of structure and behaviour that their study is treated as a branch of chemistry separate from the study of the inorganic compounds that have been discussed heretofore in this section. There is no precise line of demarcation between organic and inorganic chemistry; the simpler compounds of carbon, as well as those in which carbon is not a significant constituent, are generally studied and considered in connection with inorganic chemistry.

Originally the term organic was applied to all substances of animal and vegetable growth, and the term inorganic to those of mineral origin; and although many organic compounds have long since been manufactured synthetically, the original distinction still influences our understanding of the subject, and it is a good enough rough idea of the matter, especially for purposes of technical application.

One's general impression of such distinctions is influenced largely by typical or majority examples. One becomes accustomed to identifying organic products of vegetable or animal origin with the characteristic attributes of such matter as compared with the dead or inanimate nature of inorganic materials. We infer that organic products have a definitely limited life span, are more flexible, yielding, or malleable than inorganic materials, and more subject to decay on ageing and exposure to adverse conditions. Such a viewpoint is generally correct; but on the other hand, the number of inorganic substances of mineral origin which can be used in the arts is also limited. When one thinks of mineral substances, the first picture in one's mind is usually that of rocks and other durable, inert materials; as a matter of fact, large categories of inorganic substances, natural and artificial, are among the most unstable and violently reactive materials that exist. The organic products in approved use in the arts, while not in a class with granite or cast iron, are nevertheless adequately durable for the purposes for which they are intended and the conditions under which they are expected to survive.

Such natural organic products as are used virtually in their native states, as resins, gums, oils, etc., are not single, definite chemical compounds, but

loidal realm lies somewhere between the smallest particles visible through an ordinary microscope and the largest molecules; the largest molecule is supposed to measure much less than 1 millimicron. A colloidal solution may also be considered as halfway between a true solution and an ordinarily coarse or filterable suspension.

The tremendous extent of increase in surface produced by such minute subdivision is not always realized, but this magnification of surface area and the consequent predominance of surface phenomena is considered the chief element governing colloidal behaviour. If a cube measuring $\frac{1}{4}$ inch were subdivided into particles of the minimum colloidal size, the surface area would be multiplied by the million and would total somewhere in the neighbourhood of an acre.

A familiar example of the changes in properties caused by increase of surface is the well-known spontaneous combustion of rags, cotton waste, etc., when such materials are soaked in drying oils. Normally the oxidation or drying of linseed oil by the absorption of oxygen from the air is a mild and slow reaction, and no change in temperature can be observed; but when the oil is spread over such a finely divided substance, and is exposed to the atmosphere over such a widely extended surface, the heat developed by the reaction is so greatly magnified that it may be sufficient to ignite the materials.

Returning to our example of a colloidal solution of glue or gelatin, we find that the heavy, viscous, liquid form of this two-phase system may be transformed to another colloidal form, that of a jelly, by allowing it to cool. The transformation in this particular case is reversible; that is, the gel may be transformed back to the liquid or sol form by warming it.

It has been found that with certain two-phase systems of dispersions, not necessarily entirely of colloid dimensions—for example, in certain paints which are dispersions of relatively coarse pigments in oil—similar changes in consistency may be produced by merely shaking, stirring, or otherwise disturbing the equilibrium by mechanical means. This phenomenon has been called thixotropy, or change by touching. The theory has of recent years been applied to paints and explains certain hitherto unaccountable actions. For example, when certain mixtures of ultramarine and oil, ground to produce a stiff paste, are re-ground, stirred, or agitated, they become liquid or stringy; on being allowed to rest, they go back to the paste or buttery form. Certain heavy viscous paints which have thixotropic properties will, upon being brushed out, become fluid, causing the paint to brush easily and level out free from brushmarks.

Colloidal phenomena also contribute to the drying of a linseed oil film, to the action of lithography, the behaviour of pigments in mediums in general, and the making and use of emulsions.

Molecular Cohesion or Adsorption. The familiar word absorption which refers to the imbibing of a liquid by certain spongy or loose-textured solids through porous action, is not the same as the term adsorption, which is used to indicate the adhesion of a liquid, gas, or solid to the surface of another solid by molecular attraction.

Adsorption may be pictured as a sort of freezing or gluing on of a substance; an adsorbed layer of a material is usually held so strongly that it cannot be washed away with liquids that would ordinarily dissolve it. Gases, liquids, and solids are adsorbed equally. In the past, the term has been used mostly to describe the adsorption of gases. According to present theories, only matter whose molecules arrange themselves in a certain pattern will form adsorbed layers. The molecules of such matter have their axes parallel, all pointing in the same direction, and are described as being oriented or polarized. As previously noted, the internal structure of molecules, which we have disregarded in this account, has much to do with their actions. Adsorption in itself is not a chemical action but its occurrence is usually dependent upon some chemical reaction.

Emulsions. Emulsions are described in outline in the section on tempera painting. In order to produce an emulsion by mixing oil and water, which ordinarily are immiscible, a third substance—namely, an emulsifier or stabilizer—must be present. Some of the raw materials, which are employed for the desirable properties they impart to the finished emulsion, are in themselves very good stabilizers; other combinations of oily and aqueous solutions will not readily enter into stable emulsions without the presence of an additional stabilizer. The words oil and oily in this connection are meant to include waxes, fats, and resins.

An emulsion is a colloid or two-phase system, but all liquid colloidal solutions are not emulsions. Egg-yolk is an emulsion, the tiny globules of egg oil being dispersed in the watery ingredient. Egg-white is not an emulsion, since it contains no such dispersed oil droplets; it is simply a colloidal solution of albumen in water. A casein solution by itself is not an emulsion. But both of these colloidal solutions will readily form oil-in-water emulsions when shaken up with a vegetable oil.

A second type of emulsion also exists, the water-in-oil type, an example of which is butter, where the water is dispersed in tiny globules throughout the butter-fat, which acts as the dispersing medium. Such emulsions are evidently formed when the stabilizer is in colloidal solution in the oily rather than in the aqueous liquid. This seems to be the case when resins, water-insoluble or metallic soaps, or finely divided pigments in suspension, act as the stabilizer, rather than when water-soluble stabilizers are present.

When emulsions contain a heterogeneous collection of ingredients which contain both the hydrophile (water-affinity) and lipophile (oil-affinity) types of stabilizers, systems recognized as dual or multiple emulsions are likely to be set up; in these, the little globules of the dispersed liquid act as a continuous phase for still tinier droplets of the dispersing liquid within them. As many as five such systems within each other have been detected in microscopic examinations of such emulsions.

The dispersed drops of oil in an oil-in-water emulsion are understood to be surrounded by adsorbed films of emulsifier, but these do not protect them from breaking up under certain conditions. By the addition of enough emulsi-

fier of the opposite type, an otherwise stable and balanced oil-in-water emulsion may be transformed or inverted to a water-in-oil emulsion, the dispersed drops expanding into a continuous medium and the dispersing medium contracting into globules.

The amount or proportion of oil has little to do with this difference. Some oil-in-water emulsions contain very little oil, with the globules spread through the mass in a sparse manner; others can contain more oil than water, and still be of the O/W type, the globules sometimes being close-packed or jammed together in such a way as to distend or compress their shapes without its disturbing their adsorbed layers or skins. The same is also true of the W/O type. The subject is discussed further in connection with tempera emulsions in the second part of this section (page 318).

The study of emulsions and their applied technology comes somewhere near the head of the list of those branches of chemistry which are in an incomplete state of standardization or establishment, and a knowledge of physical chemistry and its mathematics would be required to attain much more knowledge of the subject than the inkling here presented. Most of the definitely accepted theories are of comparatively recent establishment.

Part Two: Practical Applications

The first thing to be borne in mind is that many of the artist's raw materials—oils, resins, gums, glue, casein, eggs, etc.—are natural products. This means that they are highly variable mixtures and concoctions of a number of things and so cannot be expected to exhibit exactly standard or uniform behaviour in chemical reactions as do the simple, pure substances discussed in the first part of this section. Second, with few exceptions, the chemistry of these products is not at all well established and in many cases even where materials and processes have been standardized and put under chemical control, we have, after decades of scientific study, little conclusive evidence regarding their underlying principles, particularly as they are applied to artistic painting.

A good deal of the best work on the chemistry of natural raw materials which are used for painting has been done either in industrial laboratories or by men who have approached the problems from the viewpoint of industry. This has directed research into channels not directly in line with the application of results to artistic painting, because the commercial or industrial value of these products as artists' materials is insignificant as compared with their commercial value in other uses.

There has long been an obvious need for a systematic standardization of artists' materials on a rational basis, along the lines of such rigid specifications as govern the selection of materials used by the British and various United States Government departments, the railroads, and the great industrial corporations. In these instances the standards are based on correct practice as established by experience and by research carried out for the purpose. In the past, the few attempts to establish such standards for artists'

materials have not proceeded very far;* organization of such an undertaking requires the proper sort of leadership. The standards should be set up by practical experienced artists and technicians rather than by theorists in each field; they should be independent of the bias of the manufacturers of materials, but at the same time there must be an element of justice to reputable manufacturers and due consideration of availability of supplies and the problems of distribution.

Just at present a move in this direction is being made in America under the auspices of the United States Department of Commerce, and standards of quality for artists' oil colours are being set up. Details of this work in its present state are reprinted on page 444.

Drying Oils

An oil, according to the broad and simple definition of general chemistry, is a glyceride of a fatty acid, a fatty acid being an organic acid which belongs chemically to a certain family or series of acids of similar constitution and reaction, the most important members of which occur in fats and oils of animal and vegetable origin. A glyceride is an ester or salt containing glycerin. This definition excludes such oily liquids as the petroleum or mineral oils and the essential oils, which are of different composition; these are called oils because of their external or superficial characteristics. It includes the fats; the vegetable oils are actually liquid fats. Vegetable and animal waxes are also included.

When we come to study the composition of the vegetable oils, however, we find that they consist of rather complex mixtures of a good many variants of these acids and esters with other materials, in varying proportions. The glycerides themselves are not simple esters, but triglycerides, that is, combinations of one molecule of glycerin with three of the fatty acid radicals, the latter occurring in every possible complexity of combination: they may all be the same acid, they may be two or three different acids, and the two latter combinations may appear in perhaps forty different types of arrangement. The glycerides in drying oils will combine readily with oxygen, as indicated by the fact that in their structural formulas their molecules are pictured as unsaturated; that is, their structure or arrangement includes double bonds or links which are able to combine with various numbers of oxygen atoms, depending upon the type of glyceride.

The drying properties of most oils are due to the presence of glycerides of linoleic and linolenic acids, which have the property of combining spontaneously with atmospheric oxygen to start a chain of reactions which end in the conversion of the oil to the tough, durable, insoluble film known as linoxyn. The action of moisture on certain of the glycerides of linolenic acid, particularly in the absence of daylight, is also one of the chief causes of the yellowing

* The British Standards Institution, by its constitution, is able to undertake the preparation of Standards only when requested by an authoritative body, either of manufacturers or consumers.

of oil films. Linseed oil has a larger percentage of linolenic acid and its glycerides than any other drying oil except perilla oil, which is a better drier, forms a harder, tougher film, and yellows much more than linseed oil. Compared with linseed oil, poppy oil contains a smaller total amount of these glycerides, and little or no linolenic acid, and this minimizes one of the causes of yellowing of its films.

However, because the presence of these constituents in sufficient amounts is necessary for an oil to dry in the proper manner to a tough, durable, non-shrinking, non-spongy film, the inferiority of poppy oil to linseed in this respect must be attributed to their absence. Other impurities in linseed oil, such as chlorophyll, the vegetable colouring matter which occurs in grass and foliage and becomes red, yellow, and brown as it fades, are a contributory cause of the yellowing of the oil film. They are not a principal cause, since they are almost entirely removed or destroyed during the process by which the oil is refined.

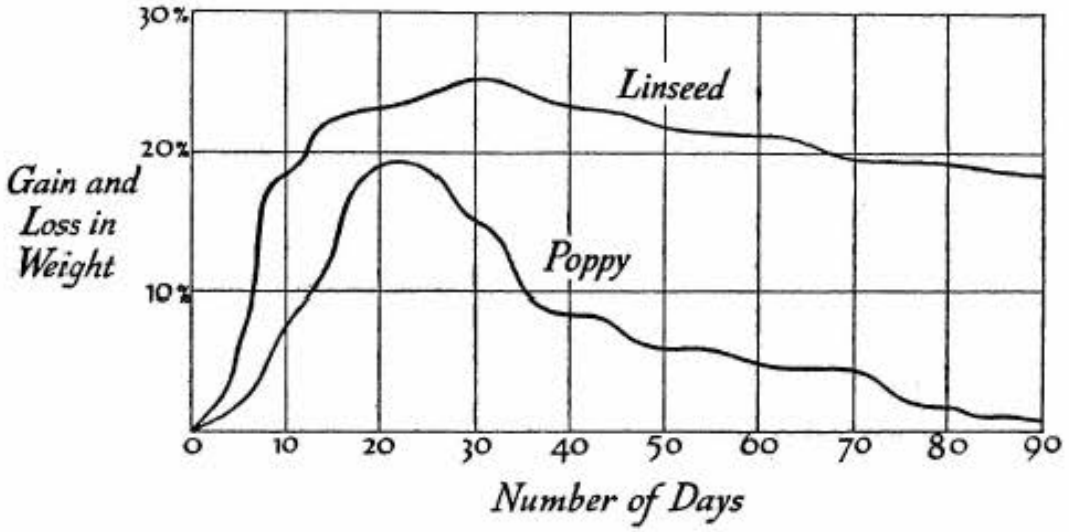
Several much-quoted letters written by Rubens[14] recommend exposure to sunlight for certain oil paintings which had in each case been boxed soon after being painted, and stored for some time. For centuries artists have known that freshly-painted oils should be exposed to daylight under normal conditions, that continual or severe exposure to bright, direct sunlight is not beneficial, and that the darkening of oil paintings from continued absence of light during the drying process is a reversible reaction which can be corrected by further exposure to daylight.

These facts have been substantiated in the twentieth century by a large amount of research by Eibner[74] and others, and considerable data on various reactions of the drying oils are on record.

The presence of normal or diffused daylight is necessary for the correct drying of an oil film, but any prolonged exposure to the direct rays of the sun is harmful, leading to cracking by reason of too rapid or violent drying action. A normal range of temperature and humidity, such as lies within the bounds of what are considered to be average, comfortable indoor conditions, is best. Excessive heat will accelerate and cold will retard the drying process; both are detrimental to the durability of the paint. After the painting has become completely dry, it will endure a slightly wider range of temperature and humidity, and should be altogether unaffected by the absence of daylight. Cracking may be caused by extreme and rapid loss or gain of weight in the oil film; the drying curves (see below) of linseed and poppy oils which have been subjected to abnormal conditions of temperature, sunlight, and humidity, will usually end in an abnormal loss of weight; the curves of poppy oil are always more exaggerated. An abnormally dry atmosphere will tend to cause more rapid drying and to show a curve which has abnormal characteristics; it is almost certain that this condition is detrimental to the life of the film. Even after oil paintings have become thoroughly dry, it is rather common knowledge that they should be kept in well-conditioned rooms, and that the dry air of some steam-heated rooms is injurious to them to almost as great an extent as is storage in a damp, unheated place.

Studies of the Drying of Oils. The drying curve is a means of graphically recording the changes which take place in the drying of an oil film; the vertical range indicates the percentage of gain or loss in weight, and the horizontal distance indicates the number of days of drying. It must be noted that in order to make a clear comparison an extremely good curve for linseed oil was chosen, and a rather poor curve for poppy oil, but the characteristic difference always exists in some degree. Eibner has recorded accurate details of such comparisons; the results of much similar work on linseed oil from an industrial rather than an artistic painting viewpoint, are also available in the scientific and technical journals.

The optimum behaviour for a drying oil is evidently for the curve to reach its height in the shortest possible time and for the decrease thereafter to be as small as possible. As indicated in the curves, the ultimate change in the linseed oil under normal conditions is small enough so that danger of



failure from shrinkage is at a minimum; the amount of change in the poppy oil is dangerously near if not beyond the bounds of safe practice. As noted under *Painting in Oil*, however, the manner in which the paint is used is probably the greatest factor in its success or failure in these respects. As shown by Eibner,[74] the drying curve of linseed oil is altered in a very harmful way by an abnormally damp atmosphere, and it is likely that a film dried in an abnormally dry atmosphere is likewise weakened, although not to such a great extent. Moist air retards and dry air accelerates the speed of drying. Drying in strong direct sunlight has an injurious effect on linseed oil and a worse effect on poppy oil. The action of various pigments with the oil, and also their mechanical effect on the structural strength of the film, are further factors in the success or failure of paints. This mechanical or structural effect may be roughly compared to the effect of sand in plaster, as explained on page 237.

The loss of weight in a drying oil film appears to reach its limit after two and one-half months with the average good oil, and, theoretically, varnishing

can safely be done after this point. However, this statement is based on laboratory tests where thin films of the pure oil without pigment are applied to glass, and conditions in an actual painting will vary so greatly from these as to make the results of such tests of little value as direct guides to practice. In general, I should say that it is better to varnish a painting a little too soon than to postpone the process indefinitely with the not uncommon result that the picture remains unvarnished and exposed to surface dangers for longer than was intended.

Yellowing of Oils. In all discussion of the yellowing of oil it must be understood, as Eibner and others have pointed out, that the matter concerns only clear oil films and the use of oils in techniques other than normal oil painting. In practical usage, correctly executed normal oil paintings do not turn yellow. The surface or protective coatings, dirt, and other removable or remediable conditions may cause browning or yellowing, but when the well-painted surviving examples of old oil paintings are cleaned of such extraneous matter, they are seldom if ever found to have suffered from yellowing of linseed, poppy, or walnut oil. It is only when the rules for correct procedure are disregarded, when inferior oils, poorly-compounded oil colours, or faulty methods of application are employed, that failures occur from this cause. The pigment in a well-formulated oil paint will mask any such slight changes; the proper dispersion of the pigment will prevent settling in the film or the formation of a layer of clear oil on top; and holding the oil content to a minimum and using the best kind of drying oil for the purpose will further safeguard the paint layer from yellowing or cracking.

Lithographic Varnishes. Lithographic varnishes, from which many types of inks for other printing purposes are also made, are heat-bodied linseed oils, very much like stand oils. A mixture of commercial litho varnishes of various degrees of viscosity will give results entirely different from those of a single, straight varnish of the required consistency, because many of the physical properties of an oil such as adhesion, levelling, tackiness, and wetting power, are appreciably changed and altered the more the oil is cooked and bodied. The mixtures will therefore consist of what we may consider different substances, or oils of different properties, rather than of merely heavy and light variants of the same oil. The thickening of drying oils is due to an increase or decrease in some sort of colloidal condition as well as to molecular rearrangement and oxidation. Recipes call for mixing various proportions of several litho varnishes, not because a single varnish of the required viscosity cannot easily be made, but because such mixtures will give different results.

The difference between a stand oil and a litho varnish is not very great, but stand oils especially prepared for paints will give better and more certain results, and litho varnishes should not be substituted for them. Litho varnishes are often set on fire for a while, as part of their process of manufacture; these burnt oils can be distinguished from stand oil by their odour.

Acid Number. Oils and resins are, as previously defined, variable mixtures of highly complex organic chemical compounds, among which are acids or compounds of an acid nature which are capable of reacting chemically with

alkalies under the proper conditions, although they are not strongly reactive substances as compared with the familiar mineral acids. For purposes of classification and comparison, and as an index of technological behaviours, an established, standard laboratory method of measuring the total amount of such reactive compounds is used; the result is expressed in figures termed the acid number. Refined linseed oils of low acid number usually run about 1 to 3, paint-grinding oils from 5 to 10.

Iodine Value. The term iodine value, which is often encountered in descriptions of oils, fats, and waxes, refers to the result of a standard laboratory test. The unsaturated fatty acids of these materials will absorb iodine; the iodine number is the percentage of iodine absorbed; hence it signifies the proportion of these fatty acids, and its magnitude is an indication of the purity and film-forming or drying quality of the oil.

Perilla oil is the only one of these materials which has a higher iodine number than linseed, some samples of it running over 200. Cold-pressed raw linseed oil has an iodine value of 177–189. Lewkowitsch[78] places walnut oil far down on the list, with an iodine value of 145, and poppy oil still lower, at 133–143.

Oil Index of Pigments

The following tables give details by which the list on pages 116–7 was computed

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	100 *Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
Aluminium Stearate	American	8	12·5	28	3·6	29
Aluminium Powder (pure aluminium, treated)	,,	21	4·8	16	2·1	44
Emerald Green	,,	28	3·6	13	1·7	47
Venetian Red (40% iron oxide)	,,	29	3·5	15	1·9	54
White Lead (basic carbonate, Dutch process)	,,	57	1·8	8	1·0	56
Spanish Red Oxide (native, 85% iron oxide)	Spain	37	2·7	13	1·7	63
Chromium Oxide Green	American	43	2·3	12	1·5	64
*Cobalt Green	Germany	44	2·3	12	1·5	65
Cobalt Violet	American	31	3·2	16	2·1	65
*Cobalt Violet	Germany	29	3·5	18	2·3	66

* Based on previously unpublished figures.

OIL INDEX OF PIGMENTS (*Continued*)

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	*100 Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
Zinc Oxide (French process, green seal)	American	47	2·1	12	1·5	71
Zinc Yellow	,,	28	3·6	20	2·6	72
French Ochre (native, 22% iron oxide)	France	24	4·2	25	3·2	76
Cadmium-barium Yellow, Light ($CdS + BaSO_4$)	American	35	2·9	17	2·2	76
Cadmium-barium Yellow, Golden ($CdS + BaSO_4$)	,,	35	2·9	17	2·2	76
Cadmium-barium Red ($CdS + CdSe + BaSO_4$)	,,	36	2·8	17	2·2	79
Cadmium-barium Maroon ($CdS + CdSe + BaSO_4$)	,,	36	2·8	17	2·2	79
*Naples Yellow	Germany	55	1·8	12	1·5	82
Indian Red (98% iron oxide)	American	43	2·3	15	1·9	83
Ultramarine Blue	,,	19	5·3	35	4·5	85
Titanium Dioxide (low absorption)	,,	33	3·0	20	2·6	87
Prussian Blue (C.P. Milori blue)	,,	15	6·7	50	6·4	96
Cadmium-barium Orange ($CdS + BaSO_4$)	,,	35	2·9	22	2·8	97
Alizarin Red	,,	14	7·1	55	7·1	100
Ivory Black (12% carbon)	,,	22	4·5	35	4·5	101
Raw Turkey Umber (native, 46% iron oxide)	Cyprus	26	3·8	30	3·9	103
*Cerulean Blue	Germany	40	2·5	22	2·8	112
Raw Sienna (native, 73% iron oxide)	Italy	26	3·8	35	4·5	118
Yellow Iron Oxide (95% Fe_2O_3)	American	32	3·1	29	3·7	119
Black Iron Oxide (98% oxides)	,,	40	2·5	25	3·2	128
Burnt Sienna (native 77% iron oxide)	Italy	29	3·5	35	4·5	129
Burnt Turkey Umber (native 53% iron oxide)	Cyprus	30	3·3	35	4·5	136

* Based on previously unpublished figures.

OIL INDEX OF PIGMENTS (*Continued*)

Pigment	*Origin*	*Weight of pigment (pounds per solid gallon)*	*100 Pounds of pigment will bulk (gallons)*	*Oil absorption, by spatula method*		
				Pounds of oil per 100 pounds of pigment	*Gallons of oil per 100 pounds of pigment*	*Gallons of oil per 100 gallons of pigment*
*Aureolin	England	43	2·3	31	4·0	174
Cobalt Blue	American	32	3·1	43	5·6	180
Lampblack (99% carbon)	,,	15	6·7	85–100	11–13	164–194
Carbon Black (99% carbon)	,,	15	6·7	85–150	11–19	164–284
Viridian	,,	30	3·3	60	7·7	233
*Cobalt Blue	Germany	30	3·3	69	8·9	270

* Based on previously unpublished figures.

The countries named under 'origin' in the above list refer to the source of the samples used; excepting Spanish red, arsenical cobalt violet, French ochre, the Turkey umbers, the siennas and carbon black these pigments are also produced in Britain.

DRIERS

The drying or the acceleration of the drying of oils by the addition of driers has been variously explained since the oxidation of oils was recognized early in the nineteenth century. The most convenient statement in the recent past has been that such action is catalysis, the drier acting as a starter or accelerator of the reaction without entering into it. Certain actions of paints and varnishes which contain driers, however, contribute to the theory that the reaction is more complex. It has been pointed out that all the salts which act as driers are those of polyvalent metals, indicating that the process involves a change from one form of molecular arrangement to another; the gelation of an oil film involves reactions of a colloidal nature which also have a bearing on the drier's action. If oil is painted out upon sheets of metal, it is well known that certain metallic grounds inhibit or retard its drying action, while others accelerate it; those substances which retard, such as zinc, are called antoxidants. Progressive drying is a term which has been applied to the continued action of a drier upon an oil film after its primary purpose (that of producing a solid film) has been accomplished; driers which display this characteristic to a marked degree have a harmful effect on the durability of the film.

Driers which contain lead or other materials which are sensitive to external conditions will impart the same colour effect to the final paint as though a lead or other susceptible pigment were used. Driers are, as a general rule, more satisfactory in artists' paints when put into solution and added to

the finished oil or medium than when cooked into the medium. The normal drying action of a pigment which produces satisfactory films with oil, such as white lead or umber, is very much more desirable than the action of liquid driers.

Colours which have been ground in poppy oil require more driers than linseed oil colours to accomplish the same effect, but because the poppy oil film is less durable than that of linseed, excessive amounts must be even more carefully restricted. Manufacturers of prepared artists' oil colours add driers to some of the slow-drying pigments, but the careful maker holds these additions to a minimum, the aim being, not to make all the pigments dry in the same length of time, but to bring the rate of the very slow driers closer to that of the rest of the palette.

Resins

The composition of resins varies considerably; those usually classified as balsams and also a few of the 'gum resins' contain benzoic and cinnamic acid; rosin is largely abietic acid and a substance called resene. Resene appears to be the ingredient which imparts durability to the harder resins. The harder copals, damar, and sandarac consist of their particular characteristic resin acids plus resene; gum Thus and the other pine exudations have a more complex composition, containing these materials plus volatile oils and some resinates (esters of resin acids). The synthetic resins are miscellaneous products of a dozen different origins; most of them are of a very complex nature.

Turpentine

Turpentine and the other products of pine distillation, such as wood turpentine, pine oil, dipentene, and terpineol, have the property of polymerizing upon ageing, and passing into other heavier, more viscous forms which are less volatile and usually have a less agreeable odour. The action is more rapid in the presence of sunlight, air, and moisture, and it is usually accompanied by oxidation. This is the reason fresh materials are always recommended, and are best preserved in full containers, brown bottles or tins. Turpentine is almost a pure, refined chemical; it contains 92 to 96% of a compound known as pinene. Wood turpentine usually contains in addition, appreciable amounts of dipentene. Pine oil is largely terpineol.

These spontaneous reactions occur very slowly; when turpentine is used as a thinner for paints and varnishes it evaporates much too rapidly for any of them to take place; it is therefore just as inert, and has the same indifferent effect upon paint films, as its petroleum substitutes. These remarks apply only to the fresh product. Turpentine which has undergone changes by reason of long storage is easily recognized upon examination; if it has lost its pleasant odour and acquired a disagreeable sharpness, or has become viscous and gummy, it should be discarded. Containers in which turpentine has

undergone these changes should be well rinsed out or discarded; a small amount of gummy residue may affect a fresh supply or speed up its reactions.

Turpentine should be kept in full, tight containers away from light; but its preservation is seldom a matter of much concern, because of its low cost and availability, and because the average painter will consume his supply rapidly.

WATER

The role of water in the various processes of the artist is considerable, yet it is often overlooked. Water is probably the greatest or most universal solvent; hence it is easily subject to contamination. Pure water will dissolve and hold in minute quantities, substances which for all practical purposes we ordinarily consider insoluble. All natural waters from springs, wells, lakes, and rivers, such as are used for general water supply, contain varying amounts of salts which have been dissolved from the rocks and earths with which the water has come in contact. Everyone is aware of the fact that excellent drinking water is often unfit for certain uses; for instance, it cannot be used in storage batteries because of the salts it contains. Hard water—that is, water with a relatively large amount of calcium salts—cannot be used for laundry work or in steam boilers without first being treated chemically.

Writers on water-colour technique usually recommend distilled water, which is chemically pure, because the salts in ordinary water are liable to break up the fine dispersion of some colours, causing agglomeration of particles, or graininess; also because of the minute cloudy or whitish film which such salts may deposit on drying. Practical water-colour painters, however, usually disregard this precaution as an unnecessary overrefinement, unless the water supply happens to be unusually bad in this respect.

It is advisable to use distilled water in the preparation of tempera emulsions; small amounts of mineral salts have a bad effect on the formation and stability of emulsions and colloidal solutions. Rain water is free from mineral salts but not altogether reliable, as it has plenty of opportunity to pick up impurities, especially if it passes through polluted atmosphere.

Fresco painters generally are very careful to use nothing but distilled water, because experience shows a decided danger to the surface effect from the introduction of small amounts of impurities. Also, mineral salts are considered to interfere with the colloidal nature and hence the plasticity of the mortar.

Water may act as a destructive force on all sorts of paintings, either by coming into direct contact with the paint film from the front or rear, or in the form of atmospheric moisture. For this reason, new plaster walls must be allowed to become thoroughly dry before oil paint or adhesives are applied to them. According to the best practice, it is advisable to wait at least three months before the application of ordinary oil paint to new walls; for permanent artistic painting and permanent adhesion of mural canvases, one must be even more careful; as much time as two years has been recommended.

Plaster applied directly to exterior walls presents a very doubtful surface for permanent painting.

The destructive alkaline reaction of plaster walls upon paint coatings diminishes with the ageing of the plaster. In industrial practice, when circumstances make it impossible to allow sufficient time for this purpose, the walls are neutralized by applying a solution of zinc sulphate of about 20% concentration; but ageing is preferable. When a wall is completely dry, the alkaline action of the plaster has much less effect upon paint coatings; moisture is necessary to cause a reaction between the alkali and the paint. According to some experienced workers, 3% of moisture is the maximum allowance for correct procedure; according to others, 5% is permissible.

An old method of testing the moisture content of a wall is to affix a sheet of gelatin to the wall by its upper edge; the moisture in the wall (and in the atmosphere as well if it is not a dry day) will cause it to curl up; if this occurs within five minutes the wall is too damp. The modern method is to use specially constructed moisture meters; one of the most convenient and accurate of these instruments is the Sunvic Moisture Indicator,* which operates on the Wheatstone Bridge principle, or the measuring of the unknown resistance, in this case the resistance between the steel points of a probe. To test a plaster surface for moisture content the points of this test-probe are firmly pressed into the material and the meter to which the probe is attached indicates whether or not that area is dry enough for painting or adhesives. The apparatus is contained within a small box, some $5\frac{1}{2} \times 5\frac{1}{2} \times 7$ inches, and is operated by a battery contained therein.

Tempera Emulsions

As stated before on page 308, the published data on the theory and practical applications of emulsions are not very complete, and there have been no exhaustive studies of the subject from a tempera-painting view-point. Most of our opinions are based on observations of an empirical nature and adapted from theoretical and industrial researches; as a result, we are still somewhat in the dark as regards a complete control over the practical technology of emulsions as applied to artists' paints.

When a tempera emulsion dries, the oil globules seem to disperse into a homogeneous mass with the water-soluble and stabilizing ingredients, so that the film takes on the character of a clear solution of these ingredients in an oil film. Laurie[34] says that the oil content alone should be sufficient to bind the pigment; as noted previously on page 116, this amount is really quite small compared with the amounts we are accustomed to employ in paints in order to grind and apply the colours. He describes some experiments to determine how much oil, according to this theory, should be added to artificial emulsions. Equal amounts of pigments are ground with different amounts of oil (thinned with turpentine to make grinding possible), until the amount of oil which will produce an adequate bond is discovered. To this

* Sunvic Controls Ltd., 10 Essex Street, Strand, W.C.2

suggestion might be added the remark that a good starting point for such experiments could be obtained by grinding a measured amount of pigment to a very stiff paste with oil, then adding an equal amount of pigment ground with turpentine; for in the case of the average pigment, 50% of the volume of oil necessary to grind the paste is not far from the amount necessary to bind the colour.

The proportion of oil to pigment thus arrived at is then to be used as a starting point for experiments in adding various amounts of the aqueous ingredient. It must be understood that this whole method is a theoretical one, to be used as a basis for experiments rather than accepted as a regular procedure. In most cases it will be found that for the production of an emulsion which is of any practical value as a painting medium, the amount of water or water solution will have to be considerably greater than these theoretical figures indicate. Pure egg-yolk, which yields a satisfactory but none too hard film, contains only about $\frac{1}{4}$ or less egg oil by weight.

Composition of Hen's Eggs. The chemistry of egg ingredients is extremely complex. Almost all of the published researches on eggs have been done from the viewpoint of nutrition and not in relation to their technical uses. The following data have been adapted from various food sources. The percentages given are average and approximate.

Whole Egg

Water	73·0%
Water-soluble ingredients	14·5%
Oily ingredients	12·5%

Yolk

Water	49·0%
Water-soluble ingredients	17·5%
Oily ingredients	33·5%

White

Water	87·0%
Water-soluble ingredients	13·0%
Oily ingredients—a trace	

Typical Analysis of Hen's Eggs

Yolk

Water	49·5%
Fat	18·0%
Lecithin and allied substances	11·0%
Proteins	14·5%
Dextrose	0·3%
Cholesterol; lutein; other substances	5·7%
Ash	1·0%

White

Water	86·2%
Proteins	12·7%
Dextrose	0·5%
Ash	0·6%
Lecithin, cholesterol, egg oil—traces	

Egg oil is a non-drying oil which imparts desirable properties to the tempera film. It is carried along by the powerfully drying and adhesive proteins to produce a film which becomes dry.

The proteins in egg are complex; they are almost all of the type which coagulate upon being exposed to the light and air in thin films. They are usually grouped together and referred to as albumen.

Albumen is an efficient stabilizer of oil-in-water emulsions. The egg oil and the albumen are the principal ingredients of the egg tempera film; the other substances contribute minor properties.

Lecithin is a still more powerful stabilizer of oil-in-water emulsions than albumen, and tends to form permanent, finely dispersed emulsions in many natural animal and vegetable products. It is classed as a lipoid, lipoids being a group of natural organic substances which have many of the properties of fats. It occurs in egg oil together with other similar compounds of which it is the principal one (about 10% of the yolk).

Lecithin from vegetable sources (principally soya beans) and from egg, is produced commercially; also egg oil that has been expressed from hard-boiled eggs. These have been applied with little success in the production of paints, but are used to considerable extent in the tanning of leather and other industrial processes.

Cholesterol, another lipoid or fat-like substance, is an important constituent of many animal glandular products and is a recognized stabilizer of the opposite, or water-in-oil, type of emulsion. Lutein is a fugitive yellow colouring matter; chemically, it is almost identical with many vegetable yellows. Dextrose is a form of sugar commonly called grape sugar. The ash is the residue left after the egg has been ignited; it consists of inorganic or mineral salts of some variety.

In the study of emulsions it is recognized that cholesterol and lecithin have an 'antagonism'; lecithin absorbs water and acts as an oil-in-water stabilizer, while cholesterol tends to stabilize the water-in-oil type of emulsion. The presence of both of these materials might possibly have some bearing on the erratic action of egg-yolk/linseed oil emulsions mentioned under *Tempera Painting*.

Tempera emulsions or painting grounds which contain wax, egg-yolk, or (especially) casein, will invariably turn yellow if they are emulsified with ordinary linseed oil; they will turn less yellow with poppy oil, and least yellow with stand oil thinned with a little turpentine. Correct procedure thus seems to prohibit, in general, the use of these animal products with vegetable drying oils. The yellowing is usually attributed to the action of

water on the glycerides of the oil during the drying process, but it is quite likely that it is increased by the action of some substance which is common to most of these animal products, because other emulsions of linseed oil, such as gum tempera, do not turn yellow to such an extent, if at all. When linseed oil is emulsified with casein the yellowing is so pronounced that casein/linseed oil emulsions are forbidden by all careful investigators; when it is emulsified with egg, the yellowing is slight enough to be controlled and kept to an acceptable minimum; nevertheless it is present.

An emulsion is usually made by pouring one of the ingredients into the other in a thin stream while stirring the mixture vigorously. In general, they are best made when both phases are of rather heavy or viscous consistency. Some emulsions will not combine without the vigorous agitation of a mixing machine, and most of them will not remain in suspension or contain very finely divided droplets unless given a complete and thorough mixing. The most convenient apparatus for the manufacture of small quantities of emulsions is an electric mixer such as is sold for household use, and if it is of the type that can be held in the hand as well as placed in a stand or holder, its usefulness is increased. Care must be taken to keep both motor and stirring blades clean; the stirrer should be cleaned and dried after each using, and the motor oiled regularly. Do not allow the cord to come into contact with liquids. The shape and size of the container should be in proportion to the amount of liquid used. If the container is quart-size or smaller, from three to five minutes' mixing with one of these little machines will usually be sufficient. When small batches are wanted—four ounces or less—emulsions may be more conveniently made by shaking the oily and aqueous ingredients together in a tall bottle no more than three-quarters full. Oil-sample vials or the common 8-ounce or 4-ounce feeding bottles which are scaled in half-ounces are convenient. Emulsions may also be made by mulling the oily ingredient drop by drop into the aqueous ingredient on a slab. On a large industrial scale, all three of these principles are used, but usually an industrial emulsion is considered crude or incomplete until it has been put through a second very powerful machine which makes the emulsion more permanent by decreasing the size of the particles. An ordinary egg-beater and jar is a less convenient but often adequate substitute for the electric mixer.

When a wax is to be emulsified it is melted, and the water or aqueous solution, warmed to a temperature above the melting point of the wax, is added in a thin stream with constant agitation. If the solution is allowed to cool too much, the wax will solidify upon coming in contact with it, and the emulsion will not be formed. A solid which has a melting point higher than that of boiling water may be emulsified by melting it and thinning it to a liquid form with an oil or volatile solvent, if such a mixture is suitable for use in the formula. All of the waxes melt below the boiling point of water and can be melted in a water bath, but when they are mixed with resins, the mixture usually requires direct heat.

Some of the modern synthetic industrial emulsifiers may eventually

prove to be well suited for the preparation of painting emulsions of improved behaviour and stability.

Glues and Gelatin

Properties and uses of glues and gelatin are discussed under *Gesso* in the section on grounds and on pages 281–2. That the chemistry of these products is not well established and the control of their manufacture is largely empirical, will be gathered from the statements in those sections.

From the maker's viewpoint, gelatin is simply a pure form of glue, made from more delicate animal tissues and refined with greater care and cleanliness than is ordinary glue. Chemically, the complex proteins of which gelatin is composed can be grouped roughly into two classes, sometimes called chondrin and glutin; the former is responsible for its adhesive properties and the latter for its gelation. Glue contains more chondrin and less glutin than gelatin.

Technologically, the difference between glue and gelatin is considerable. The user of both of these products regards gelatin, not as a purified glue, but as a material of the same origin, with similar properties, especially when used as a size, but of different behaviour when used as an adhesive or binder. The difference in composition is one which involves colloidal as well as chemical properties, and the behaviour of each of these materials as an adhesive or as a constituent of a binder or film-forming medium, is different from the behaviour of the other. The best grade of bone glue is inferior to all but the very lowest grades of hide glue.

The highest-grade gelatin will make the strongest jelly, but its binding, adhesive, and finishing properties will not equal those of the high-grade skin glues. Rabbit-skin glue has the correct balance of properties for use in gesso. The calf-skin glues are so pure that they may be considered gelatins from the manufacturers' viewpoint; nevertheless, they have the adhesive strength of hide glues and are also balanced enough for use in gesso. Selection of a glue for technical purposes is usually based upon the correct balance of properties rather than upon one desirable property. A heavy viscosity in the liquid state is apparently considered an indication of a glue's adhesive strength, and is also a desirable quality for uses where too much penetration is not wanted, as in application to cloth when it is undesirable for the liquid to soak entirely through to the other side of the fabric. The jelly strength is a definite indication of a glue's value for sizing, gesso, and some other binding purposes.

Glue, gelatin, casein, albumen, egg-white and yolk, all belong to the same class of products of animal origin (proteins). One of the properties which members of this particular group happen to have in common, is the ability to form viscous colloidal solutions in water; and one of the reactions some of them display is a property of being coagulated or denatured when exposed to certain conditions, such as heat (as in hard-boiled eggs) or sunlight (as in drying of egg tempera). Glue dries and hardens to form adhesive or binding layers, but none of its original properties are changed, and sub-

sequent application of water will redissolve it. Casein forms similar dry films of adhesive or sizing qualities, but these films are not so completely soluble in water. The dried product resembles the original casein, which did not dissolve without ammonia; it is therefore very definitely more resistant to moisture than is glue. It is a mistake, however, to consider casein films or paints completely waterproof. Compared with those of glue, they are merely more resistant to disintegration by moisture—in many cases sufficiently resistant to suffice for certain purposes where glue would fail; but casein paint films and gesso may be picked up or disturbed by water to a considerable extent.

Glue and casein paint films, putties, gesso, and the like, may be enormously improved, to an extent that will render them more impervious to atmospheric moisture (and for all practical purposes to applied water or aqueous mediums if these are carefully handled and not scrubbed in), by the application of certain chemicals which have the property of toughening, hardening, or tanning them. Here again, the resulting surfaces are sometimes inaccurately called waterproof; their resistance to moisture is increased appreciably, but water, although it will not completely destroy them, can, if not carefully applied, damage them severely. The differences between glue and casein hold true in the tanned products: the chemically hardened casein is proportionately more moisture-resistant than the chemically hardened glue. In industrial use, solutions of the following materials may be added to the batch or sprayed on to the surface to harden glue and casein films: alum, chrome alum, sodium or potassium bichromate, and tannic acid. But although these chemicals are or have been used industrially, they are not to be recommended for materials for permanent painting, because their products will remain in the film; therefore more volatile substances are employed for artists' purposes. The best hardeners belong to a class of completely volatile materials of which formaldehyde is the most widely used example; the best hardener for casein, glue, or gelatin is a 4% solution of formaldehyde, which is brushed or sprayed directly on to the film. A 40% formaldehyde solution is universally obtainable in drug stores, usually under the name of formalin. Its highly penetrating, unendurable fumes are familiar to most people through its use as a fumigant; however, when it is diluted with nine parts of water to give the 4% solution, it can easily be handled, and there is no irritating effect on the eyes and throat.

Acetone also has a powerful coagulating or flocculating effect on casein and aqueous colloids in general, but it is not generally used in this connection; no controlled definite recipes for its application as a hardener of such films are in circulation.

All of the above-mentioned materials can be added directly to glue or casein liquids so that they will harden to tough, water-resistant films, but the disadvantages of the films containing such active chemicals is obvious. The behaviour of glue and gelatin is tricky and erratic in this respect; such hardening materials must be added to them just prior to use, and must be very delicately controlled; there is less difficulty in the case of casein; the

commercially prepared adhesives described on page 279 contain many such materials, and the industrial flat casein wall paints sold in paste or powder form usually contain lime, which not only assists in their solution but has the property of increasing their resistance to washing. For permanent artists' materials, spraying with the formaldehyde solution is the most approved method of hardening or tanning casein or glue films. A recipe for the addition of formaldehyde to a casein solution is given on page 277. Great care must be observed during the mixing.

It is neither necessary nor desirable to heat glue or casein over 160° F.; heating to the boiling point is definitely destructive and spoils the product for use in any exact formulas.

The addition of small amounts of alum (about 5%) to hide glue or gelatin in order to harden it and render it less hygroscopic for use as a sizing for paper and for other uses requiring weak concentrations, is a procedure which has been employed effectively since early times. It is not used with bone glues; when alum is added to a solution of bone glue the solution becomes muddy or turbid. This reaction can be utilized as a test to distinguish hide from bone glues.

Plaster of Paris and Gypsum

When native calcium sulphate (gypsum, $CaSO_4.2H_2O$) is roasted at 212–374° F., it loses three-fourths of its water of crystallization and becomes $CaSO_4.\frac{1}{2}H_2O$, the familiar plaster of Paris. When mixed with water to a plastic consistency or a heavy cream, it takes up the one and a half parts of water again, and when dried, hardens to a uniform solid mass which is inert and no longer reacts with water. If plaster of Paris is soaked in a large excess of water, enough so that it settles to the bottom of the vessel instead of forming a paste, it will take up the water and become inert in the form of fine particles without solidifying to a continuous mass. The material has enough hydraulic characteristics to set, at least partially, under water; therefore it must be stirred often during the first thirty minutes of slaking, and once every day until it is smooth and creamy, after which setting will not occur. Chemically, both the slaked and the hardened plaster of Paris are the same as the original gypsum, but they differ from it and from each other in crystalline structure.

Use in Gesso. As noted under *Gesso*, Cennini used slaked plaster of Paris as a pigment for gesso. The painters of his day and locality used it because it was the most brilliantly white, inert, and pure material of its type widely available; but when whiting in uniform, pure grades became an article of commerce, it replaced this material. The very fine Paris white was a further improvement, and precipitated chalk a still later one. In accounts of other countries and times, chalk is as frequently mentioned as gypsum or plaster of Paris for use in painting grounds.

A chemically precipitated calcium sulphate is also available; under the microscope, the particles of this variety show up as long, needle-shaped

crystals which have a tendency to mat or felt with each other. For this reason some writers of the past have recommended slaked plaster of Paris for producing a gesso of superior durability or elasticity. Finely powdered native gypsum and slaked plaster of Paris, however, do not have this monoclinic crystalline structure to any marked degree; moreover, it is extremely difficult to obtain any of these products in a pure state, free from lime or other alkaline impurities.

Pure plaster of Paris when mixed with an equal volume or about one-third its weight of water will set rapidly, becoming hard and solid in five to fifteen minutes. This is the reason why plaster of Paris is used for moulding; the speed of its setting is greater than that of the evaporation of water; hence there is no shrinkage. Most other plastic materials shrink upon setting. Plaster of Paris hardens best in a dry atmosphere. It sets because of its slight or partial solubility; the small amounts in solution crystallize out and interlock or cement with the insoluble particles in a way similar to that in which lime sets. The addition of as little as $\frac{1}{4}$ of 1% of hide glue will delay its setting for two hours. Slow-setting and medium-setting plasters are sold ready-mixed with retarding ingredients. Gypsum and plaster of Paris were used in the earliest primitive civilizations.

Keene cement is a thoroughly burnt gypsum from which all the water of crystallization has been driven, and it contains additions of alum or other salts. It dries to a very hard mass and is used as a patching plaster for walls and in places where the surface may be subject to much wear.

Soap and Saponification

Soap is made by boiling an oil, fat, resin, or wax with an alkali. The water-soluble soaps used for washing purposes are made chiefly from vegetable oils and animal fats. A carefully made neutral soap, such as cake shaving soap, Ivory, Lux, etc., contains no alkali; however, when it is mixed or dissolved in water, a minute amount of alkali is produced by a chemical reaction (hydrolysis)—sufficient in many instances to alter the surface colour effect of a painting. The principal action underlying the functioning of soap as a detergent or cleanser is generally supposed to be a colloidal one; the various theories which have been advanced are based on various interpretations of the chemical nature of dirt. The particles of dirt are usually considered to be more strongly attracted by the soap solution than by the substance which they stain.

The removal of varnish from paint with soapy water is clearly, from observation, a process of solution, accompanied (or preceded) by some saponification, which is probably the most essential part of the action. Disadvantages of the use of soap for this purpose, other than those enumerated in the discussion of the cleaning of oil paintings, are: (1) colour particles are drawn into the soap solution from an otherwise seemingly unaffected film, (2) soapy water seeping into cracks does far more harm than plain water, and (3) the presence of dirty suds hinders visual control of the progress of the work.

Some dirt films are attached by superficial adhesion, some by adsorption; those of an oily nature can be removed by aqueous solutions only when they are emulsified by soap, or saponified (made into a soap) by free alkali. Free alkali will attack and sometimes destroy adsorbed layers.

The so-called metallic soaps, whose manufacture also involves the saponification of oily materials but which are insoluble in water, are described on page 148.

LITHOGRAPHY

From the period of the development of the lithographic process down to recent times, the chemical principles underlying the various attractions and repulsions peculiar to lithography were not entirely explained in a way satisfactory to workers on the subject. The usual explanation that the free fatty acids combined immediately and directly with the stone to form calcium oleates, etc., and that the natural acid of the gum formed arabinates, was not convincing to those who were familiar with the feebly reactive nature of the acids of oil and gum. The improbability of the occurrence of such reactions with infallible precision under the variable conditions present in lithographic practice, was noted, but until recently was not proved.*

The conditions set up in the stone are not caused by superficial coatings of oelates, arabinates, and other products of reactions which could be dissolved with solvents, but are permanent effects in the stone itself which are produced chemically and can be removed only by mechanical means, that is, by grinding the layer completely off the stone.

The action, according to modern investigators, is adsorption, a reaction referred to in the first part of this section. Many substances, particularly when their surfaces have been recently and carefully cleansed, have the property of adsorbing layers of acidified gum arabic and lithographic crayon to produce conditions under which lithography is possible. According to this theory, an adsorbed layer of fatty acids is formed under the crayon marks, and non-polar deposits incapable of adsorbing fatty acids are set up on the rest of the stone by the acidified gum arabic of the etch. These layers are so thin as to be immensurable; it has even been suggested that they are monomolecular, because of certain theories of adsorption.

The animal and vegetable oils, fats, and waxes of the lithographic crayon contain fatty acid molecules, which are capable of forming orientated layers, as previously described in this section under *Adsorption*. If pure mineral oil, which has a different molecular arrangement, is applied to a sensitive stone, it will not set up a lithographic printing condition; if minute amounts of fatty acid are added to it, a very slight smudging effect will be produced, because the material then contains some traces of orientated acid molecules. These facts contribute toward the proof of the present theory.

The reason why lithographers have found it wise to allow the etch or

* Tritton, F. J., 'A study of the theory of lithographic printing.' *Journal of the Society of Chemical Industry*, Vol. 51, pp. 299–306, 307–313. London, 1932.

gum solution to dry before washing it off is that a very concentrated solution of gum is required, and this is most easily obtained by allowing the solution to dry down on the stone.

The operation known as rolling up is important, because it speeds up and completes the process of adsorption by means of mechanical pressure, an established way of accomplishing this.

ETCHING

Preceding remarks on the nature of acids will throw some light on the reason for accurate formulation of etching mordants, both as regards choice of acids and concentration.

In the first place, a certain optimum dilution with water is required to secure the proper dissociation or ionization of an acid so that it may act most efficiently on a metal. An extremely violent action is not desirable, because it would be uncontrollable and probably erratically uneven, and also because the force of the bubbles of a violent ebullition and the heat generated thereby would have a mechanically destructive effect on the fragile coating of resist, particularly where there are delicate lines.

Sometimes when a metal is immersed in a full-strength acid—for example, zinc in concentrated sulphuric acid—the metal becomes almost immediately coated with the end product (zinc sulphate), which effectively protects it from further action by the acid; if the acid were diluted with water, this salt would go into solution as soon as it was formed, and the metal would remain clean and exposed to the action of the acid as long as desired.

On the other hand, a too dilute solution is also impracticable; the length of time a plate would have to remain immersed or in contact with the acid would eventually cause the ground or resist to be affected; the etcher also wants a certain amount of continuous bubbling to occur so he may know how the reaction is proceeding and thereby be in control of it. False biting through the failure of the resist in spots can be immediately observed by the bubbling, and steps can be taken to stop it by rinsing the plate, drying it, and giving these places an additional touch of acid-proof varnish or resist.

Copper is much less reactive chemically than zinc; comparatively, it can be classed among the inert or durable metals.

11

Conservation of Pictures

This chapter is not designed to be a complete manual of instruction; should some of the data seem to be presented in too great detail in proportion to their importance, it may be explained that this is done because these facts, some of which are common knowledge to experienced restorers, have hitherto remained unpublished, or because published accounts of them are vague, contradictory, or not readily available.

The modern tendency is to refer to this subject as the conservation of works of art; this term includes all measures taken and studies made for the purpose of rehabilitating damaged or deteriorated works and preserving or maintaining works of art under correct conditions. Restoring refers only to the replacement of missing portions, imitating the original by the use of paint or building up missing fragments of sculpture. The distinction is a proper one, but it still seems convenient for the general art public to refer to the entire subject in ordinary conversation as restoring and to call its practitioners restorers.

Proficiency in restoration is not entirely a matter of fundamental artistic and chemical knowledge, materials, methods, etc.; these are necessary equipment, but their successful application is a result of expert skill and a sense of judgment developed by experience. Apart from understanding the strictly technical aspects of the craft, the worker must have an adequate comprehension of the artistic nature of the work upon which he is engaged. Toch[102] mentions preliminary experience and studies on the subject, and recommends continued study and experiment upon old and worthless pictures in various stages of decay. Perhaps the paramount consideration is the restorer's attitude toward the work; the pictures entrusted to him should be treated in a conscientious manner to the best of his ability, uninfluenced by other considerations. A well-qualified restorer may sometimes resort to unsound procedures, not through ignorance, but because of various circumstances.

In connection with this type of work, inexperienced persons means persons who have not completely restored hundreds of old paintings and so become thoroughly familiar with the emergencies that suddenly arise, with the little differences between one painting and another which may indicate totally different methods, or with the dozens of variations of cause and effect for which there are no written directions. The term inexperienced also includes the professional painter with a successful restoration or two to his credit. An experienced restorer is continually learning.

It is expected that the information in this section will be utilized by the amateur; the foregoing remarks are intended to impress upon him the necessity of knowing how much he dare attempt, and under what circumstances the work may be within or outside his capabilities.

General Rules. Most of the rules and instructions for restoring have exceptions, modifications, and limitations; these should be more or less obvious to the intelligent operator.

In attempting restorations, try to avoid doing anything that cannot be undone; keep it possible to return the picture to its *status quo* if necessary.

Do not treat a dilapidated canvas which is to be restored as though further rough handling will not matter. The difference between an ordinary restoration problem and a complicated or hopeless case is often slight. Also, every new blemish means just so much more work. The most troublesome operations the professional restorer is required to employ are often those made necessary by previous unskilful attempts at restoration.

Attempt should be made to save every vestige of original paint; repainting should be done only where all original paint is missing, as in the case of holes, burns, etc.

Too little perfection is preferable to overdone restoration. Work must be planned in advance in this respect, and judgment exercised in its execution.

Excellent restoration has been practised for a good many years. Generally speaking, the old, well-tried methods are superior to the more recent ones, but a considerable number of the modern materials and recipes are superior to the old.

As mentioned in the section on painting in oil, linseed oil is not a particularly good adhesive or glue. Therefore remember that a powerful glue is not necessary to make paint adhere to canvas; what is more important is stability—the power of the binding material to 'stay put' or remain unchanged under normal conditions. In the same connection, it should be borne in mind that conditions only slightly away from normal tend to destroy this adhesion.

One of the most powerful enemies of oil paintings is water, including water vapour or moisture in the air. Canvas is commonly sized with glue before an oil ground is applied. The picture consequently is separated from the cloth by an exceedingly thin layer of glue; if this be moistened from the back, the picture may immediately detach itself from the canvas. Water seeps through cracks and fissures when applied on the face of a painting and may produce the same effect. It is inadvisable to use water or mixtures containing water for cleaning most old pictures, and when the experienced restorer finds it necessary to do so, he will use it as sparingly as possible and dry the picture thoroughly immediately afterward.

Proprietary nostrums for the cleaning and 'regeneration' of paintings, whose composition is never published, bear the same relation to correct restoration as patent cure-alls do to the practice of medicine, and should be strictly avoided.

Repainting. From the very beginning of restoring, so far as can be learned from old writings, correct attitude and taste, and propriety of results, have been matters of great concern to those interested in the conservation of art; some of the earlier writers are surprisingly in agreement with much modern thought on the subject.

The use of restoration, in the narrower sense of the word as previously defined, must be strictly limited to the replacement of missing parts, and none of the original paint should be concealed. Various writers have proposed different approaches to repainting; in the case of a valuable artistic work, it is generally desirable to recondition the picture so that repairs are not readily apparent but so that upon close examination all the restored spots may be detected without trouble. Some of the suggested methods of accomplishing this are to use an entirely different technique of brush stroking from that used in the surrounding paint (hatching, stippling, etc.), to model fillings or plugs so they lie slightly below the surface, to paint them carefully but in colours a shade or two away from the surrounding areas, or to leave them vague or blank, tinted to match approximately the surrounding paint.

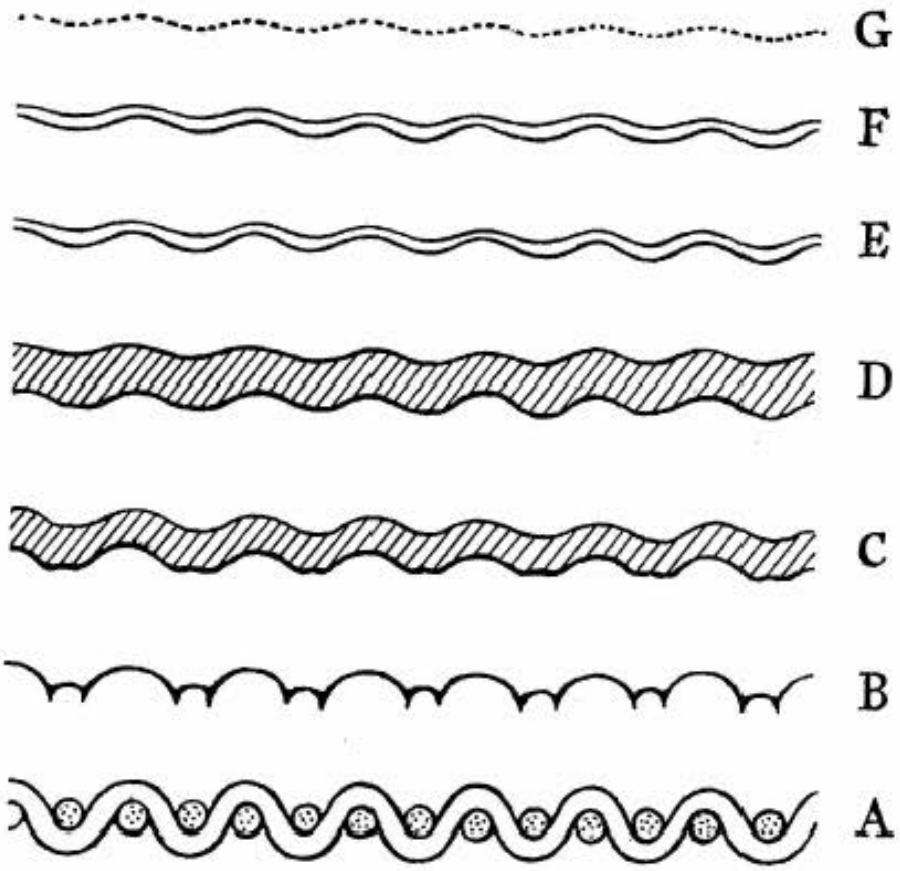
In the case of a semi-valuable painting regarded by its owner primarily as a wall decoration or of a portrait which is valued for reasons other than its artistic or historical value, the restorer is usually called upon to duplicate its original condition without blemish. In the instance of a modern work which has become damaged, particularly when the original artist repairs it or supervises its repairs, the same flawless perfection is required. Flatly painted areas such as plain backgrounds, or small lacunae in areas of single, flat tones, which bear no particular relation to individual draughtsmanship, are completely restored in almost all cases.

In writing descriptions of specific restoring processes, it is usually necessary to proceed on the assumption that a complete, flawless result is desired, and to leave the distinction between restoration and original work to the judgment of the restorer, whose decisions will usually be dictated by the conditions and auspices under which he works.

Relining

When injuries or decay in a painting on canvas have occurred to such an extent that patching, retouching, or other simple treatments will not rectify the defects or check the future disintegration of the picture and preserve it indefinitely, the painting must be relined.

This procedure consists in mounting the entire picture, including the old canvas, upon a new support, usually a new linen canvas. Logically the process should be called lining, but it is universally referred to as relining, a term which refers specifically to the conservation of decrepit paintings by this means. Canvases may be mounted on wooden panels for further rigidity, but this is usually considered an inappropriate alteration of the original work; furthermore, many old restorations of this kind have developed blisters,



ANATOMY OF AN OIL PAINTING

(Reading up from the bottom of the diagram)

A—Linen support.
B—Glue sizing.
C—First coating of ground.
D—Second coating of ground.
E—The painting. This may be one simple, directly applied paint-film, or it may consist of several layers, e.g.,
1. Underpainting
2. Overpainting
3. Glazes or scumblings
4. Isolating varnishes or veils.

F—Picture varnish.
G—Dirt.

warping, and cracking, defects which would not have occurred if canvas had been used; also, eventual further restorations are made more difficult. Except under unusual, special conditions, canvas is preferred. When additional rigidity is desired for any special reason, a well-braced Presdwood panel is better than wood—at any rate, in this climate.

Relining methods may be classified into two groups, according to the type of adhesive used: aqueous or non-aqueous. The former is the traditional and still the customary method; the latter is preferred by modern, scientific workers. The choice of materials should be determined by the nature of the defects, the degree of correction required, and other circumstances, but the

non-aqueous adhesives are to be favoured whenever they can be successfully applied.

The usual procedure, based on traditional methods, is to stretch the new linen on a temporary stretcher, eight or ten inches longer each way than the original, and give it a good sizing with a weak solution of hide glue or gelatin. The linen should be strong and of the best quality. As with linen that is prepared for artists' canvases, its weight should be sufficient to withstand all the strains to which it will normally be subjected, and a flat, square weave with identical threads in the warp and woof is most desirable.

For small pictures, up to 24 inches or thereabouts, the ordinary stretcher bars will serve for the temporary frame, but because longer stretcher frames will warp and twist in an annoying manner, careful workers use heavier wood for larger canvases, 2 × 2 or 2 × 4, joined with iron angles. The outline of the picture area may be ruled on both sides of this canvas with a pencil.

If the paint film is decrepit and likely to part from its canvas, paper is pasted over its surface, as described under *Transferring*. Some restorers recommend this in all cases, others only when they deem it necessary, but it is always safer to do it, especially when using an aqueous adhesive. The picture is then carefully and neatly cut from its original stretcher; sometimes the tacks are first removed with a screwdriver and the margin trimmed off with scissors or a sharp blade. When the picture is to be replaced in its old frame (and so far as circumstances permit, in every case), care must be taken not to diminish its size. A painting which is dilapidated around the edges is often trimmed to a smaller size by the restorer when with a little extra care and time he could preserve its full original size.

The back of the picture is gone over with sandpaper if necessary, to remove all knots and irregularities, and then scrubbed with a whisk broom. Previous to this, all significant inscriptions or stencilled marks should be photographed or carefully traced and preserved. Hot glue is than applied to the front of the new canvas within the pencilled outline; after it has set sufficiently, second and third coats may be applied, according to the restorer's judgment and experience. The glue should be applied with a wide flat varnish or enamel brush, and great care should be taken to keep the layer smooth and uniform. A typical mixture is French rabbit-skin glue, heavy wallpaper paste, and Venice turpentine. Three ounces of the paste are dissolved, free from lumps, in 10 to 12 fluid ounces of water and mixed with 6 fluid ounces of glue which has been soaked overnight in cold water, drained, and melted. An ounce or two of Venice turpentine is then emulsified into the hot glue-paste mixture with an electric mixer. Glue without paste will shrink too much and will not give a structurally durable film. The Venice turpentine imparts a little flexibility; also, without it the glue will not have the desired adhesive tackiness or penetration. Many other aqueous adhesives, including the casein-latex cement, have been recommended for relining. Glue and paste mixtures should contain a little preservative (see page 283) in order to prevent the formation of mould, should the painting be stored under conditions which would encourage its growth.

The back of the old painting is then given at least a thin coating of the hot glue and placed on the glue-covered area of the new linen. The canvases are pressed together with a rubber roller, or by rubbing with the palm of the hand, care being taken not to exert enough pressure to disturb the uniformity of the glue layer. Blisters or air bubbles are avoided by rubbing from the centre outward. Pieces of plywood, Presdwood, or other boards of the correct size (larger than the picture but smaller than the inside dimensions of the temporary stretcher) are useful for building up a support under the temporary stretcher so that this and other operations on the surface of the picture can be done against a solid backing. The picture is then set aside until it is nearly but not quite dry, after which it is ironed on the back with the heaviest sort of tailors' iron (about 20 pounds is a desirable weight; a lighter iron is less useful). A continuous gliding motion should be used rather than a pronounced stroking. The purpose of this ironing is to force the adhesive through the old canvas to the back of the ground, and also to cause a smooth, level condition. If the iron is too hot, it will cause the glue to liquefy to a greater extent than is necessary and to flow unequally. If the iron is too cool, the glue will not liquefy sufficiently to penetrate into the old picture and strengthen the adhesion of the ground to the canvas. Very hot irons will sometimes burn the paint.

For this operation the picture must lie face down on a perfectly smooth, hard surface; Presdwood free from blemishes is a good base. If the picture has any sort of impasto or sharpness of brush stroke, the points must be preserved by interposing a piece of blanket material, a pile fabric such as thin velvet, or other fairly thick, soft cloth between the table surface and the face of the picture. A small spot or point of paint raised any considerable distance above the level of the picture will be flattened out by pressure against an unyielding surface; this might not be so very harmful, were it not for the fact that the point is then likely to be surrounded by a small crater or concavity which will emphasize its crushed condition. Ironing the face of the picture is generally to be avoided; the experienced worker will know when it is necessary; and whether he irons it directly or protects it with a piece of cloth, he will take great care that the iron is not hot enough to burn the paint. Beeswax or paraffin may be spread over the surface to allow the proper slip and protection. When the picture is perfectly flat, it is ready to be cleaned. If paper has been pasted upon it, it is rippled off after sponging it with warm water. This water must not be allowed to soak into the picture, but it must wet the paper thoroughly; some skill must be exercised. The Presdwood or plywood panels mentioned earlier are useful as a support in such an operation. A painting will often require an additional ironing after removal of the paper.

Some writers recommend that ironing and other operations be carried out after the picture is on its final stretcher; this is a more cumbersome procedure; it requires the use of handled implements, made of thin wood or sheet metal and resembling trowels or mortarboards, for working on the parts of the canvas which lie over the stretcher.

Pressure in Relining

In the published accounts of restoring techniques, little or no mention is made of the use of presses and clamps during relining, yet they have been used to a considerable extent by professional restorers. A study of all the literature on the subject of restoring tends to give one the impression that their use is not in accordance with approved practice or that it is unnecessary. Yet old paintings which underwent relining seventy-five years ago or more, and which are in perfect condition, often show unmistakable evidence of pressure. All scientific and technical accounts of other adhesive procedures assume that pressure during the hardening of glues is essential.

By far the greater number of old paintings which require reconditioning present complications of more than one defect, usually rendering the literal application of published instructions impossible, as these instructions almost always assume that the defect under discussion is present in an otherwise intact picture. This is particularly true in the case of those pictures which have as an additional defect an irregularity of surface that requires flattening.

Very often an old painting on canvas has an all-over crackle which creates a sort of swollen, rounded effect, each unbroken area seeming like a raised island in the network of cracks; sometimes these areas are concave or sunken. Such irregularities of surface are caused by the unequal tension put on the fabric by the unbroken areas of paint and glue size, and the network of cracks where the film is discontinuous. It is often impossible to spread a coat of relining cement to a sufficiently uniform thickness so that the particular canvas being treated will be perfectly flat; in some cases the adhesive's slight variations in thickness, or unequal tension, will be transferred to the surface in the form of bumps or other irregularities. Often such conditions cannot be corrected by repeated ironing, but they may be minimized and usually entirely corrected by a skilful application of pressure.

The piling of weights on the average painting is usually ineffective; an enormous weight is necessary to equal the pressure of the most indifferently powerful press or clamp. The work of professional restorers will naturally be greatly facilitated by a properly designed press of a size large enough to accommodate most pictures; it may be specially constructed, adapted from machinery intended for other purposes, or improvised according to the ideas and resources of the restorer, and may operate on a number of fairly obvious principles. Good results, however, may be had by using large-sized carpenters' or cabinet makers' clamps, the advantage of a press over these being principally one of convenience. The all-metal clamps are more desirable than the wooden ones.

Pictures may be pressed between plywood panels of convenient size; the five-ply $\frac{13}{16}$-inch panels described under *Wooden Panels* are good for this purpose; another satisfactory material is a plywood of approximately the same thickness but made of five plies of maple of equal thickness in place of the thick softwood core and the four thin plies of hardwood veneer of which the other panels are constructed. This wood is not used in ordinary decorative

or structural woodwork, but is made expressly for mechanical and technical purposes such as the present one, and is less likely to warp and more likely to stand up under hard wear than the other. Pressure may be distributed by an arrangement of wooden strips or bars; 2 × 2 or 2 × 4 lumber, if it is not too badly warped, will serve the purpose.

An adequate supply of Presdwood is also very convenient; when it is used together with the heavier panels its smooth side may be placed against the picture; it is also useful as a smooth flat surface for ironing upon, and in the manipulation and handling of canvases generally. As mentioned before, when a canvas is mounted on a temporary stretcher, it is often convenient to have a panel or several sheets of Presdwood cut to a size around which the stretcher will fit so that work of various kinds may be done on the face of the picture while it is resting flat on a solid surface.

With canvases in a press, the same precautions must be taken as in ironing; if they have impasto or sharply pointed brush strokes, these must be protected as previously described so that they are not flattened out. When an aqueous adhesive has been used to reline a painting and ironing is not effective in producing a flat level condition, the canvas may be pressed after redampening the back of the new linen with a wet sponge. This procedure, of course, has all the disadvantages mentioned by those who oppose the use of water in relining, but in experienced hands it should not be dangerous. After the canvas and glue have absorbed a fair amount of moisture and have once more become uniformly damp and flexible, the canvas is placed under pressure for about forty-eight hours, preferably longer. Sheets of waxed paper should be used to prevent the moist canvas from sticking to the press boards, and strips of it may be placed along the borders of the face of the picture where the glue may have spread through the edges. Waxed paper may also be placed over the entire face of the painting when necessary, but the edges of the sheets are then liable to impress their marks on the picture. Waxed paper is useful in a number of other restoring manipulations but cannot be used against the face of a picture when heat is applied. It is not wise to wet the margin of the new canvas too much, as the glue around the edges thereby becomes too moist; the moistening should be confined as much as possible to the back of the picture area.

Upon removal from the press, the picture should be stretched without delay. Even if it seems perfectly dry, it usually retains sufficient moisture to cause buckling and inequalities if it is allowed to remain exposed to the air for long without being stretched. If the temporary stretcher is still attached, however, the canvas may be held taut enough to prevent this. Sometimes the procedure of dampening and ironing the canvas is repeated several times in order to flatten obstinately uneven pictures, because ironing or pressing will have little effect unless the picture is in a malleable condition. This moistening and steaming of the canvas is a good reason for preferring non-aqueous adhesives, as discussed under the next heading.

For various reasons it is sometimes desirable to reinforce a canvas by gluing a strip along a side or sides where the canvas goes over the stretcher,

instead of relining the whole picture. These strips may be glued on with strong relining glue, care being taken that their inner edges do not extend beyond the part of the picture concealed by the rebate of the frame. The strips should be wide enough for their outer edges to extend about 2 inches beyond the edge of the picture, so that they may be properly stretched. If raw linen is used, such strips should be impregnated with glue size before being glued on, and after they have been ironed or put through a press between strips of wood they should be painted with a good oil paint; their back sides may also be sprayed or brushed with formaldehyde if desired. The inner edges may be ravelled, as explained in connection with glued patches. Linen for this purpose should be strong but of a lighter weight or more open weave than the usual canvas type, and the glue should be applied evenly and not too heavily, or buckling may occur.

Non-Aqueous Adhesives for Relining

In several places throughout this book the harmful effects of water upon paintings have been noted. Water mixed into oil colours, especially when emulsified, produces weak, spongy films and favours rapid yellowing of the oil. Moisture in the atmosphere has its deleterious effects; water is generally taboo in cleaning old paintings on account of its effect on the entire structure of the picture.

For some years, many writers on the subject of relining and mounting oil paintings have declared that the water content of relining glues is likewise injurious, especially when the damp canvas is ironed: that the steam generated thereby is destructive, the entire painting weakened, and the cloth liable to shrink and cause loosening or flaking of paint or ground. Such writers are theorists more often than experienced restorers, but their opinions are not to be taken lightly on this score; it is quite likely that the moisture's penetration of the size which isolates the linen from the ground and of the ground itself if it contains glue or casein, may leave the painting in a weakened state. The alternative to an aqueous adhesive is a wax-resin mixture; such a mixture, however, has not been accepted to any great extent by professional restorers for reasons already outlined. Most old paintings suffer from a multiplicity of defects and the adhesive waxes do not meet the complete requirements in many cases, especially in regard to the appearance of the restoration; however, they do give good results when the picture is not too badly wrinkled, buckled, or otherwise irregular in surface. When a non-aqueous adhesive is developed which will give as satisfactory visual effects as the aqueous mixtures, it will no doubt be universally adopted because of its being less injurious to paintings. The attitude of the writers who favour the non-aqueous adhesives is that the painting should be conserved in the most permanent and harmless manner down to the last possible precaution, even at the expense of the completeness of the restoration; the attitude of the professional restorer who is guided by the preferences of the average patron, is that no process is correct and successful that does not put the picture in as

unblemished surface condition as possible. The latter point of view has accounted for much damage to valuable paintings in the past.

A typical formula for a non-aqueous adhesive is the following, taken from the publication mentioned under *Transferring:*

5 parts beeswax
3 parts rosin
1 part Venice turpentine

The harder and less brittle damar resin may be substituted for rosin if desired. The mixture may also be thinned with a very little turpentine for ease in application in certain uses; when this is done, it is assumed that the user will provide for the complete evaporation of the thinner during the progress of the work, either by ironing or by exposing the wax coating to the air for an hour or so before joining the two fabrics.

This is one of the few recipes given in this book which involve the direct heating of inflammable materials; the melting point is rather high for the mixture to be made conveniently in a water bath. However, if the can or vessel is not too full, and a metal plate is placed between it and the electric coil or gas flame, the fire risk is not great. If the mixture is to be thinned with turpentine, the light should be extinguished, and the can removed from the stove before stirring it in. The Venice turpentine is stirred in last, after the mixture has been removed from the stove.

Materials of this nature are applied to the back of the old canvas and to the prepared side of the new canvas (best quality prepared artists' oil canvas can be used instead of the plain linen employed in glue relining), which are then pressed together with warm (not hot) electric irons. Care must be taken to making the coating thick enough to provide a good bond, and thin enough so that it is possible to manipulate the iron without getting into trouble on the score of having the wax melt and run into unequal ridges and wrinkles. Care taken in applying a very even, uniform coating of wax with the brush or spatula will repay the worker in this respect.

When unprepared linen is used instead of oil-primed canvas, it is difficult to prevent the wax from running through it during ironing. The account mentioned on page 339 recommends the application of the wax to the old canvas, followed by a thorough ironing until, upon turning the picture over, the wax is observed to have come through the cracks of the old painting and to have soaked into the protecting paper. The new linen is then laid on and given just enough ironing to create a perfect and uniform bond between it and the softened adhesive wax.

The use of any appreciable amount of turpentine in wax adhesive is unwise; it will produce a salve effect like that of floor wax, with the result that the coating will be too tender, and the picture too susceptible to denting from minor contacts. For smoothing the wax on the mounted canvases, one may use electric irons of various weights, from the heaviest sort as used in glue relining, to those of smallest size, such as the rectangular irons and the tacking-iron sold for the mounting of photographs.

The purpose of ironing a wax-mounted canvas is to bring it to a smooth

level condition, and to impregnate as much of the entire structure as possible with wax. Sometimes obstinate spots may be flattened by a careful application of spot pressure, as described under *Patching*.

TRANSFERRING

Some conditions of structural decay cannot be rectified by relining, but by their nature require the removal of the paint film from its old support and the remounting of it upon an entirely new support; the most approved procedure is to use the same type of support as that originally used, unless some complex condition requires a change. In reconditioning a very decayed painting, the restorer must determine for himself whether transferring is required, or whether relining will suffice.

The removal of the paint film from the ground, or of the paint film together with the ground from the support, is a delicate and painstaking operation; yet it is not always so desperate or dangerous a measure as is popularly supposed. All conservation processes, even the most simple, demand of the operator the same skill and expert care; transferring differs from the others only in requiring a greater amount of time and painstaking effort.

Among the paintings so handled in the past are many well-known early Italian works which were transferred from panels to canvases in the eighteenth century after being brought to Paris.

The first procedure is to paste a sheet of plain newsprint paper over the surface exactly as in the relining of decrepit or flaking oil paintings. Strong flour or starch paste is used; it may be brushed on the picture as well as over the paper; should the paper become accidentally torn to a minor extent during application, it may be patched with a bit of paste-soaked paper; after the patch is dry a light sandpapering will remove the bump. Irregularities such as wrinkles (which a skilful operator will avoid) and overlapping of sheets may likewise be made smooth by a few rubs with fine sandpaper, after the paste has become thoroughly dry. Other materials have been recommended by various writers: layer on layer of tissue paper until a sort of cardboard has been built up; muslin or mosquito netting as either a first, intermediate, or last layer, with tissue paper; cartridge paper; and laminated cardboard. Some special papers are used by professional restorers. The main requirements for a paper for this purpose are that it should be of such a nature that it will serve as an adequate bond and protection for the paint film and not present too much resistance to removal at the end of the process. The newsprint paper referred to should be of ordinary quality; it is widely available in 50-pound rolls about 40 inches wide.

After the paste has dried thoroughly and completely, the canvas is cut from the frame; if it were cut from the frame before pasting, it would buckle and curl up during the drying of the paste. There is even some likelihood of this occurring after the drying, and the careful restorer will guard against this. He may handle a small picture as it is cut from the frame, or he may reinforce it by stiffening the edges; if the paper was made ¼ inch or more

larger than the painting all the way around, strong kraft or gummed paper strips may be pasted to this margin and folded under to make a sort of marginal frame. The picture may also be held flat, face down on the table or drawing board, by the use of gummed strips on this margin, or by weights.

However, the most convenient and safe method of handling the picture is the following, which is based on an account by Dr. F. Schmidt-Degener of the Ryksmuseum, Amsterdam.* The procedure described in the original account is the removal of an old glue relining and its replacement with a new piece of linen attached by the wax-resin mixture referred to under *Relining*, but the method outlined is also well adapted to the entire removal of the old canvas. The picture is first cut from its stretcher and four strips of heavy kraft paper about 10 inches wide or more, depending upon the size of the picture, are pasted along each of its edges not more than an inch in, on the face of the canvas. These strips are then pasted securely to a flat wooden frame made large enough so that there is a margin of 7 or 8 inches all around, between the canvas and the frame. The strips are then soaked with water and allowed to dry overnight, after which, if the work has been properly done, the paper will have stretched tight and the old canvas will be held in a taut, flat condition. (I have also used a single large sheet of kraft paper with the picture shape cut out of its centre and squares cut out of its corners where it folds over the corners of the frame.) The face of the painting is then protected by pasting over it squares of tissue paper overlapping each other by more than $\frac{1}{4}$ inch. (A single sheet of newsprint paper may also be used successfully.) When the paper has dried, the picture, thus mounted, is laid face down on a table and held rigid by iron weights on the corners of the frame.

The removal of the old canvas is accomplished by dampening it with a sponge, whereupon the linen, which is usually isolated from the ground by a layer of glue size, will become detached and may be carefully peeled up. The safe removal of the linen calls for patience and skill gained by experience; in many cases knives, abrasives, sponges, etc., must be used. After the canvas has been removed, exposing the back side of the ground, all traces of the old sizing must be scraped away from the ground. In a case of the removal of an old relining, a relatively thick coating of old glue must be removed; the account referred to recommends that equal tension be maintained on the old canvas by dividing it into squares and removing the glue with damp sponges and rounded knives in alternate squares, so that when the work is half finished it will present a checkerboard effect. The moistening of old canvases without these precautions of stretching, pasting, and gradual, uniform application of the water, is most liable to lead to damages to the painting through the too sudden shrinkage of the linen.

The new linen is mounted on a temporary stretcher just small enough to fit within the wooden frame upon which the old picture is mounted, and cemented to the back of the old picture in the manner of the relining process. The type of adhesive in each case is to be chosen according to the requirements of the work and the experience of the worker. The last operations are

* The *Museums Journal*. Vol. 32, pp. 86–87. London, 1932.

the cutting away of the paper frame and the careful removal of the newsprint or tissue with warm water and sponges, an operation which is not so difficult as it is tedious. A number of sheets of plywood or Presdwood cut to the proper sizes will aid in pressing and other operations, as previously described.

Pictures are similarly removed from wood panels by pasting a rather heavy protective layer over the surface and reducing the thickness of the panel to the thinnest sort of film, which can then be scraped away from the ground. The thickness is reduced by planing or by the use of a machine saw which can be set so that its penetration is limited. The back of the picture is crisscrossed with saw cuts, which are made as deep as is deemed safe, and then the squares are knocked out with a chisel. Murals have been safely transferred from plaster and masonry walls by laboriously chipping away the support from behind with a chisel. Sometimes such a picture, with its pasted gauze and paper protection, is rolled directly on to a large cylinder as it is separated from the wall, and is carried to a studio for complete removal of the adherent wall fragments, and for relining and repairing.

Patching

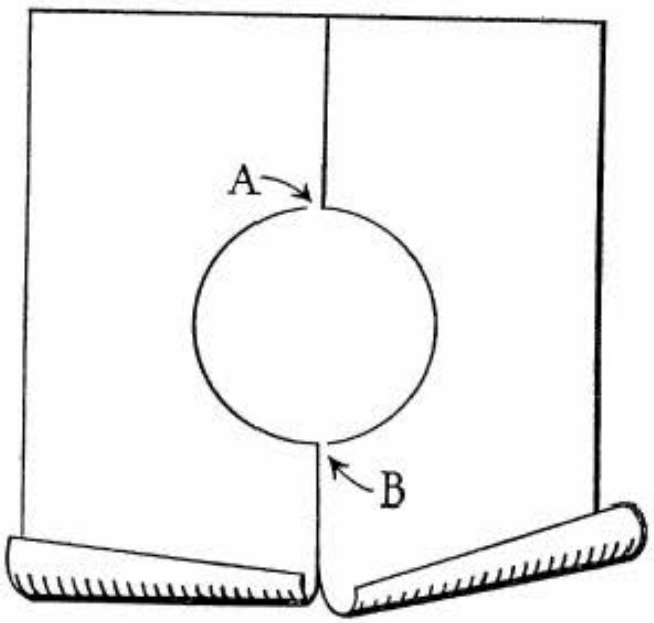
Small punctures and larger tears may be repaired by applying individual patches behind them, provided the painting is otherwise in good condition. The adhesive used is either of the wax-resin or of the aqueous glue type. The former is the easier to apply; it is less likely to make a mark on the face of the painting at the edges of the patch, and is more in accordance with the most approved modern practice. Also, it is more easily removed, if this should subsequently be necessary for any reason. The glue patches are more useful when the tear is accompanied by any considerable amount of wrinkling, buckling, or pulling of the threads, because the dampening of the canvas and subsequent application of pressure is more effective than the other procedure in correcting such defects; but when the buckling is not too pronounced the wax patches will also accomplish this purpose. Most patched spots will require filling in, as described on page 349.

The damaged canvas is laid flat and the edges of the tear fitted together; all overlapping threads or fibres, especially those which have a tendency to protrude upward, are trimmed with a sharp blade. A patch is cut from prepared oil canvas, and coated on the primed side with the wax-resin compound mentioned on page 337, placed behind the damage, and carefully pressed flat with a warm, not hot, iron. The heat and pressure should be just sufficient to create a flat level condition; too much will cause the wax to run in an irregular manner; too little will not allow it to penetrate and adhere permanently to the fabric. Some of the wax may appear around the outside of the patch; if it does, it should appear evenly all around; if desired, it can be neatly scraped or cut away after it hardens. The layer of wax should be fairly thick. A rubber roller may sometimes be found useful in making such patches flat.

Before the wax has become entirely hard, weights or slight clamp pressure may be applied to the patch in order to assure a flat level surface, if it seems necessary; not so much pressure should be used that the wax is forced out.

These operations are performed with the painting lying on a smooth table; for manipulations which require work on the face of the picture, the canvas should be supported from behind with several sheets of wallboard or a piece of wallboard resting on blocks, etc., as noted previously. The excess wax which fills the cavity should be carefully scraped out as thoroughly as possible, and the damaged spot or slit filled in and touched up with paint, as described farther on. This type of patch can be pulled off with the fingers quite easily; it is a good idea to make it round or oval, so that the danger of accidental pulling up of corners is minimized.

Sometimes when paintings have been patched with the wax adhesive, pressure applied to the face of the picture in handling it during the subsequent filling in, repainting, or other finishing operations, is sufficient to make the edges of the patch show through on the face of the picture; even the ironing may have this effect. To guard against this, I have used a method whereby the patch is incompletely cut out of a much larger piece of canvas, thus:



The patch is applied in the manner previously described and the entire square of canvas is allowed to remain until the job is completely finished, when the tiny connections A and B are cut with a keen blade and the surplus pieces pulled off. Bigger patches may have more than two of these points if desired. The square should be larger than the iron or at least large enough to bear careful pressure of the iron without its edges becoming imprinted on the face of the picture. The wax adhesive is applied to the patch and the corresponding area of the original canvas only; the ironing may cause some of it

to exude under the surplus canvas, but this does not prevent easy peeling off of the latter, and the excess wax may be neatly cleaned away later.

Pressure may be applied to patches of any kind by the following method: carefully round or bevel the edges of square pieces or strips of Presdwood so that these edges will not be impressed on the canvas; place one of the pieces on each side of the patched spot, and over each a piece of wood of somewhat smaller area (if aqueous glue has been used, slip a piece of waxed paper under each piece of Presdwood to prevent it from sticking); hold the arrangement in place with a screw or spring clamp. If the patch is far from the edge of the picture and only small clamps are available, an arrangement of wooden bars and blocks with clamps at either end can be improvised.

Aqueous Glue Patches. The big disadvantage of this method as compared with the preceding one which employs a wax adhesive is that the more powerfully adhesive glue will almost always pull or pucker the canvas around the patch, and make an irregularity which is clearly seen on the face of the picture.

Instead of prepared canvas, square or oblong pieces of plain linen are used, and a few strands are pulled out along each side. If the ravelled sides are kept as straight and smooth as possible, the effect is that of a bevelled edge which has less tendency to impress its design on the face of the picture than a sharply trimmed edge.

The linen is applied with hot glue of the type used in relining; the mixture may be thinned down somewhat with water, leaving it strong enough to supply permanent adhesion but not so strong that it has a puckering effect on the canvas. This is not a simple matter and requires some experience and judgment. Some writers recommend light-weight muslin or gauze for this purpose, but old pictures patched with these materials and glue often show the same kind of pucker or patch mark as is produced by linen and glue.

Woven or Mesh Patches. Nail punctures and similar small holes or slits may be patched by weaving a few strands of linen together, laying them over the back of the tear (Scotch tape will assist), and impregnating them with glue; when the glue has set partially, it is covered with a piece of waxed paper; rather mild pressure is applied with a clamp thirty-six hours or so, in the manner previously described. Fish glue, slightly thinned with water, seems to be satisfactory for such patches. They are inconspicuous in appearance and do not affect the face of the picture. Even on larger holes and tears, when there is not too great a space, I find that these patches, because of their open-mesh structure, hold plugs firmly and do not cause wrinkling. The wetting with glue and subsequent pressing will flatten puckered or wrinkled tears more successfully than will the wax-resin method. Too much pressure may produce an impression of the woven threads on the surface. Other more intricate methods, which include weaving in strands of linen, are practised by expert restorers; they call for considerable skill, patience, and ingenuity.

The wax-resin patches are the easiest ones for the non-professional restorer to use, as in the case when an artist must mend a tear in one of his own

works. Older methods of sticking on muslin or gauze patches with shellac, powdered resins, etc., have been more or less discarded, as they tend to give brittle, non-permanent, or blistery results.

Blisters and semi-detached pieces of paint may be glued down and pressed, if glue can be inserted under them. Such operations call for some practice and skill. A hypodermic syringe is often useful for inserting the glue behind blisters and other raised areas; in this case it is necessary to make a small hole by puncturing the film with a solid needle before inserting the hollow needle. It is sometimes recommended that these spots should first be softened with solvents, but this procedure is not always useful. The impregnation of a loosened surface by flooding it with gum, resin-varnishes, or oil, is likewise of doubtful value, except in some unusually complex cases.

Because of the difference in textural and colour effects between fresh repairs and old surfaces, all repairs such as patching, relining, and filling-in must be followed by cleaning and revarnishing operations whether or not the original surface condition of the picture was poor enough to have required such treatment had the structural defect not been present.

Cleaning Paintings

Removal of Old Varnish

The removal of old varnish by dissolving it and washing it away is not, according to universal opinion, to be carried to the point where the painting is denuded of every trace of its protective coating, because this is liable to result in the condition which the restorers call skinned. A painting so scoured presents the characteristic appearance of having had a minute amount of its surface peeled off; delicate tones, glazes, and lines are often partially or completely destroyed; points of white or pale-coloured ground or underpainting will show up in a sort of granular or stipple effect over large areas, and the entire colour effect may be altered so as to appear clouded. It is desirable, therefore, to proceed with the solvent under such control that a minute amount of the original varnish, made thoroughly uniform and dilute by the solvent, will be left. This can be done if the solvent is correctly applied; the surface will appear thoroughly clean, yet a very small trace of varnish will remain upon it. Among professional restorers, the operation of removing the varnish from a picture is called stripping.

The standard method of removing varnish from a painting by use of solvents is to apply the materials with small wads of absorbent cotton such as is sold in chemists'. This cotton is not only safe so far as abrading or tearing up delicate surfaces is concerned, but it also applies the solvent in a controlled manner and reabsorbs and holds in the greater amount of the dissolved material. Its whiteness and purity make possible a close observation and control of the amount of film being removed. The best grades, put out by the well-known makers of surgical dressings, have long fibres and are most satisfactory because they are free from the fuzzy lint of the cheaper

grades; but the cheaper grades sold in one-pound rolls under the name of hospital cotton are also adequate, and often seem to be more absorbent than the more expensive varieties.

In describing the usual method, we will assume that we have an average, well-painted portrait about a hundred years old, covered with a film of old varnish which has turned a dark brown colour and which is encrusted with accumulated dirt that seems to have become occluded into the film.

If the picture has been relined and is still on its temporary stretcher, it is laid upon the supporting boards mentioned on page 333; if it is on its permanent stretcher, cardboards must be stuck under the canvas and made rigid by being supported with blocks or boards of the proper height to fit between them and the table. This is to preclude undue flection of the canvas and to prevent the worker's bending the canvas over the inner edge of the stretcher, which would result in marks or cracks. Under no circumstances should pictures be cleaned with solvents in other than a horizontal position. The surface grime is first removed with balls of cotton which have been dipped into a non-aqueous liquid that has little or no solvent effect on the varnish, such as turpentine, mineral spirit, or solvent naphtha. The cotton should be well squeezed out so that it is just moist. This preliminary operation is not absolutely essential, but a heavy superficial coating of blackish dust often obscures the colour of the varnish and interferes with one's judgment of the progress of cleaning. Next, the solvent is selected according to the judgment and experience of the restorer, or after preliminary trials at the edge of the picture. Suppose a mixture of five parts of alcohol, three parts of turpentine, and one part of ethyl acetate is chosen: an ounce or two is poured into a suitable vessel and a wad of cotton is dipped into this and rather well squeezed out. The wad should then be compact and not more than about an inch and one-fourth in diameter, or small enough to be conveniently held and controlled between the thumb and two fingers. It is applied with a circular or back-and-forth motion, care being taken to keep the strokes small and to complete the removal of varnish to the desired extent before moving on to the next area. The rubbing face of the wad is continually examined for any traces of colour, and should the greenish, yellowish, or brownish colour of the removed varnish show any marked change, or should there be any other indications that traces of colour are beginning or about to be removed, the action is immediately halted by application of turpentine; an open container of turpentine and a well-soaked cotton wad are kept available for the purpose. The action may sometimes be more closely controlled by continual alternate applications of turpentine and cleaning solvent, one wad of cotton for each held in either hand.

When the face of the cotton has become saturated with varnish, it will neither distribute further solvent nor absorb more in the correct way, and it is turned around so as to present a fresh surface; one may usually use three sides of a wad, then tear it open and get one more useful surface from the interior. The used balls of cotton should be thrown into a container and disposed of as soon as the work is over.

When small spots of varnish of a greater thickness than the rest of the coating persist after the bulk of the surface is perfectly clean, or when such spots are found to be drops and spatters of a less soluble material, it is always dangerous to attempt their removal by continued scrubbing with the solvent, because the clean areas surrounding them are most likely to be skinned, every trace of varnish being removed. The paint film in those areas, if not actually picked up, will then be exposed to the danger of becoming weakened, softened, or altered in colour value by the continued action of the solvent. The removal of such spots is best accomplished with the knife, in the way in which fly-specks, spatters, and freckles are removed. (See page 348.)

The ideal volatile solvent or mixture of solvents will contain no water; if ordinary alcohol or a mixture which contains it be compared in practical use with a solvent which contains anhydrous alcohol, it will be found that in many instances the surface of an old oil painting will be bloomed or whitened by the solvent which contains a little moisture, and that it will not be so affected by the anhydrous solvent. It is possible that the water content of some alcohols will be great enough to produce all the undesirable and harmful effects which follow the application of water to an old, cracked oil painting. The anhydrous denatured alcohols described on pages 267 and 439 are miscible with turpentine. Anhydrous alcohol, ethyl acetate, turpentine, xylol (or toluol), and mixtures of these solvents are sufficient to carry on most picture cleaning manipulations; acetone and some of the other more powerful or special materials are useful in special cases. As mentioned under *Volatile Solvents*, the principles underlying solvent action and the behaviour of mixed solvents are rather complex; the properties of the different solvents are best learned by experiment. There does not seem to be any general rule or test for determining which solvent or concentration is best in any given instance; the worker must be guided by experience and by the results of careful preliminary trials.

Areas of paint composed of lead pigments which have become darkened by the action of sulphur-bearing fumes from a polluted atmosphere can usually be restored to their original colour by the application of hydrogen peroxide with a cotton wad. This reaction has been known since the early nineteenth century, when hydrogen peroxide was first obtainable.

Castor oil has been recommended for retarding and controlling the action of solvents, especially alcohol, on a painting; and according to Laurie[34] an undesirable absorption of alcohol by the paint film is thereby diminished. He recommends coating the picture with the oil and applying a mixture of alcohol and solvent into this with a soft brush, having more castor oil available to retard the action if it becomes necessary. He does not approve of the 'harsh and wholesale' absorbent cotton.

Castor oil serves another purpose in the removal of varnishes and repaints. One of the most successful paint-remover patents employs a waxy material dissolved in the volatile solvents. The wax not only holds the solvent in place so that it will not flow from vertical surfaces so easily, but it also keeps the solvent in contact with the paint or varnish for a longer time than

if the solvent's evaporation were unhampered. It is occasionally necessary to apply the strongest possible solvent action to an intractable painting; an addition of castor oil, 25% or less, will sometimes increase the solvent action of alcohol, apparently by holding it on the surface for a longer time. A wax salve made by thinning molten beeswax or paraffin with turpentine may also be used as a base for solvents.

If castor oil has been used in the cleaning of a painting, every vestige of its oiliness must be rinsed off with repeated applications of solvents, because it is an entirely non-drying substance, and paint or varnish applied over a trace of it may remain sticky for months. A disadvantage in its use on old paintings is the difficulty of removing it entirely from deep cracks and the canvas under the cracks; in my opinion, its use in general is rather unwise.

Soap and other powerfully detergent chemicals are ordinarily taboo in the cleaning of pictures. In the past, pure, neutral soaps have sometimes been recommended for perfectly intact, uncracked surfaces, but their use is never really safe, especially in the hands of an inexperienced worker.

The experienced restorer can often make good use of cleaning materials and methods which would be dangerous in unskilled hands, and there are, as has been previously noted, exceptions to the general rules and prohibitions, particularly in the case of such expert workers. The use of soap solutions by persons of limited experience is perhaps the cause of more injuries to old paintings than is any other procedure; although pictures may sometimes be cleaned successfully by this method, the number of old paintings which have suffered damage from it is quite large. The only alkali which has been given any sort of approval is ammonia, which is volatile and leaves no residue; its action, however, may sometimes be destructive so far as the life of the paint film is concerned, and it is not to be used except in very special cases and by experts. Laurie[34] quotes a recipe of Dutch origin for a cleaning agent made by treating copaiba balsam with ammonia, adding the latter drop by drop with continuous shaking until the mixture becomes clear and has a faintly ammoniacal odour. This combination is a powerful solvent, but its action may be controlled to some degree and is immediately arrested by an application of turpentine or kerosene. It works well, without apparent harm to old paint films. Saponin or powdered soaptree bark, which foams and duplicates part of the action of a soap solution without any of its dangers to the paint film, has also been recommended. Its value for delicate surfaces is well known and there are no objections to its use in cleaning pictures other than those which apply to water alone.

Pettenkoffer Method. Some cracked, dead-looking, or otherwise deteriorated varnish films may be 'regenerated' by exposing them to the action of alcohol vapours, which cause the surface film (especially when it is mastic varnish) to coalesce and appear as though it were in its original state. The process is named for its inventor, Pettenkoffer, and was in considerable favour during the nineteenth century, but because the varnish tends to revert to its former bad condition upon further ageing, and in some cases to

become even worse, the method has more or less fallen into disrepute. The fumes have a slightly similar effect when applied to a resinous or bituminous painting which contains wide traction fissures, but hardly enough to be of much practical value in the restoration of such pictures. Liberal application of copaiba balsam to the surface assists and improves the Pettenkoffer process. The procedure is best carried out by laying the picture face up in a shallow box made of sheet metal, to which a well-fitting lid is applied. The lid is lined with absorbent cotton held in place with wire screening, and the cotton is well soaked with alcohol, but not to such an extent that it will drip.

In practice, the process is ordinarily less desirable than the procedure it was designed to supplant, namely, the removal and replacement of old varnish. The action of fumes of alcohol and other volatile solvents can, however, be useful as an intermediate stage in some complex restoration processes.

Repaints. It is not always possible or desirable to preserve repainted areas or former restorations when cleaning an old painting with solvents; they are usually removed and, if necessary, replaced.

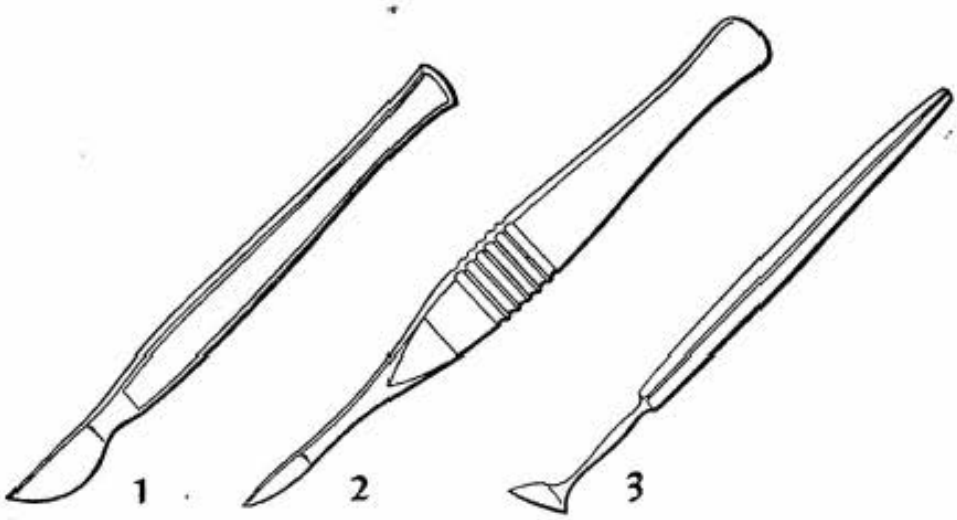
After the painting is cleaned, it is allowed to dry until it is free from tackiness; any necessary patches or fillings are made, and before these are repainted the entire picture is given the thinnest sort of coating of damar or retouch varnish that will produce a uniform gloss. The colours are thereby brought out in their final effect so that the repaints may be made accurately. When flat (mat) varnishes are used, they will occasionally seem to discolour the repaints unless these are first isolated with a very thin protective coat of glossy varnish. Some workers recommend coating all repaints with a thin isolating varnish which is insoluble in the solvent used in the finishing varnish; others condemn the use of any such intermediate varnishes, and bring out the tones for repainting by applying copaiba balsam considerably diluted with turpentine, a very thin layer of which is generally considered without harmful effect on the structure of the complete film. This subject is continued on page 351.

Cleaning Paintings without Solvents

The cleaning of paintings with solvents may be inadvisable or impractical in many instances, and methods are resorted to that may be classified as mechanical as distinguished from those using solvent action.

The older books on the subject describe an abrasion or attrition method for removing films of varnish (particularly mastic), which consists in crushing a bit of mastic, damar, or rosin, and rubbing it with a thumb or finger-tip (protected by a piece of gold-beaters' membrane) into the varnish film. The powdered mastic acts as a starter, the rubbing is done firmly and in small circles, and the varnish will continue to dust up and be removed. This procedure is practical only on works of the most level smoothness; the grooves and pits of brush strokes, canvas weaves, etc., will mostly remain untouched. The method is no longer widely used.

Use of Knives. In many cases the use of a knife or scalpel is the safest and best way to remove varnishes and overpaintings, especially from complex or delicate paintings. It is particularly effective when it is necessary to remove heavy repaints in oil or tempera from a delicate surface. The type of knife designated No. 1 in the accompanying drawing is best for general use in the removal of varnish; the blade, though small, is rather heavy. It is, however, necessary for complete practice to have an assortment of lighter blades for various contingencies, and instruments for special needs; these can be found among surgeons' instruments; they can be altered or ground down to serve various purposes. Modern scalpels with thin replaceable blades are not always good for this purpose, as the blades do not have sufficient weight.



Obviously, considerable experience and practice are necessary to gain expert control over such manipulations. Although the method is slow and tedious compared with the use of solvents, very precise work may be done; films of varnish and paint can be taken off without disturbing delicate glazes or scumblings, and dirt or varnish may be safely removed from the most intricate surface irregularities. Even a fraction of a film may be removed, and the depth of scraping is at all times entirely under control. For the removal of maculae and small, thick areas of varnish from an otherwise clean surface, this method is the only satisfactory one.

When it is used by a person of limited experience, the errors which are likely to ensue will usually be much less serious in extent and nature and much more easily corrected than those caused by an inexpert use of solvents. The blades must be constantly sharpened on an Arkansas oil stone during their use. The scraping is ordinarily done dry; an occasional wiping of the picture with cotton moistened with a liquid inert to the materials being worked on will bring out the colours, if desired. In some special instances it may be advisable to soften a heavy, oily coating with solvent before using the knife.

Mould (Mildew)

Exposure to strong sunlight (or ultraviolet light) and fresh air usually destroys and stops the growth of mould on fabrics. Provided a painting will withstand a cautious application of water, mould may usually be removed from its surface by rubbing with absorbent cotton moistened with a 10% solution of magnesium fluosilicate (silico-fluoride), rinsing off the solution afterward with cotton moistened with distilled water. This method will leave a minute amount of the chemical on the surface, which will guard against the recurrence of mould. Make sure the substance is really mould by examining it with a microscope or magnifying glass, because whitened varnish or oil and crystallized or powdered salts are often mistaken for it. Some other fungicides are mentioned under *Preservatives*.

Mould is a kind of fungus, the spores of which thrive on sized fabrics, glue, paint films, wood, etc., and once it flourishes, it will spread to adjacent surfaces of nearly any nature. Mould begins as a white, feathery growth, developing quickly into a denser and more or less coloured substance, depending upon its species. The commonest types are *Penicillium*, usually green, and *Aspergillus*, usually black or blackish, but many other varieties also occur. Various materials will grow certain types more rapidly than others.

The growth of fungi is encouraged by warm, humid, dark surroundings, and occurs most frequently on paintings which have been boxed and stored in the hold of a ship. It also flourishes in liquid paints, aqueous solutions of gums, etc. Mould should not be confused with bacteria.

Filling in Holes and Tears

After a painting has been relined and cleaned, or a damaged spot backed up with a patch, the holes, slits and flaked areas must be filled up level with the surface. In England this process is called stopping. Two general types of plastic material are in use, an aqueous glue plaster of the order of gesso, and a linseed oil-whiting mixture similar to common putty. The use of commercially prepared crack-fillers (both those sold as plastics with a varnish base, and the dry powders intended to be mixed with water) is inadvisable, not only because of their doubtful composition but, chiefly, because of their extreme hardness when dry. In general, materials which dry to a very hard consistency are not so good as those which are somewhat softer than the surrounding paint film; they seem to be less permanently adhesive and more liable to crack.

Another method of filling in places where the canvas is missing is to procure a piece of canvas of identical weave, lay it face up beneath the damaged spot, and with a keen, pointed blade cut around the tear or hole, just trimming off its edges, and at the same time cutting through the new piece of canvas. This will produce a patch or canvas plug which will fit the hole exactly. Such plugs must be used at the time when the patch or relining is applied. Great care and dexterity are necessary to get good results with this

method; the weave of the patch must line up accurately with the weave of the original canvas.

If a flawless job is desired, every spot where the paint or ground has become detached from otherwise intact canvas must be filled in before repainting, but in ordinary cases, superficial scratches and minor flakings are often touched up without first being filled in.

Plastic Gesso. Dissolve ½ ounce of casein in 3½ fluid ounces of water, according to any of the instructions under *Casein Solutions*. Emulsify with ¾ fluid ounce of damar varnish by shaking together in a bottle; mix to the stiffest possible paste with whiting or chalk as required, using a spatula or stiff palette knife on the rubbing slab. Other glue and casein gesso formulas may be used, with or without oil or varnish additions, according to the user's preferences, so long as they are made in the stiffest possible form with as little water as possible to minimize shrinkage, and so long as they comply with other obvious requirements. Is it not advisable to use plastics which are deliberately formulated to give a crackled effect; if such imitation of the defects of the picture is required, it is best produced by carving with a needle or by other artificial means. Pigments may be added to the whiting if it is desired to match any special colour.

Imitation of Textures. When the gesso plug is nearly dry and almost completely set, soft enough to receive impressions but firm enough so that pressure will not pick it up, a piece of cloth or canvas which matches or closely approximates the weave of the original canvas is pressed upon it in order that the texture of the repaired spot will be the same as that of the surrounding parts of the painting. Restorers can save for this purpose scraps from the edges of canvases they have relined, and sometimes one is able to steal a small scrap from the edge of the stretcher without harm.

All attempts to match weaves and textures require great care. Even a fairly smooth picture will require some roughening of a gesso plug to prevent a slick shininess. It may be pointed out that pressure of cloth produces a reverse or negative of its weave which sometimes appears very different from the surrounding area.

Picture Putty. Rub stand oil with whiting or chalk to a stiff paste with a spatula, then knead in more chalk by hand, rolling the putty between the palms; this is a rather sticky job at the start, but with a little practice one can do it efficiently, using dry chalk as a baker uses flour. The rolling warms the mass and softens it so that more chalk can be folded in until the mass becomes less sticky; finally, the stiffest sort of putty is produced. If desired, a few drops of syrupy cobalt linoleate added to the oil will make this material dry more rapidly.

One of the heavy white pigments (zinc or titanium) should be added to the chalk in sufficient amount to produce an opaque colour; also, any pigment or mixture of pigments may be added to produce useful shades. The bulk of the filler, however, should be chalk or whiting, which reacts definitely with the oil to form a putty-like mass, and which also imparts a desirable texture.

The paste may be moulded into conveniently shaped pieces and kept in

tight jars; the wrinkled skin which forms on the surface is peeled off before use. There is no danger that such wrinkling will occur in the small and comparatively thin layers in which the putty is used on pictures. This material is to be employed where more flexibility is required than the gesso plug presents. Canvas weaves may be imprinted upon it the same as upon the gesso plugs; this may be done as soon as the putty is smoothed. Whiting or other pigment may be dusted on the putty with the finger to prevent it from adhering to the cloth, should this be found necessary. Picture putty may be applied over a first layer of gesso, if desired.

Manipulations. The manipulations involved in the stoppage or filling in of lacunae, may be facilitated by the use of a good many types of instruments. Doerner[38] recommends kneading a plastic putty into tiny pills and rolls and pressing them in with the fingers, allowing them to set partially and then wiping off the excess with a well-wrung cloth which has been dipped into copaiba balsam thinned with turpentine. All traces of excess putty are to be removed from the surrounding parts at once. The area is also to be slightly moistened with the balsam mixture before the plastic is used.

I find that certain small blades and surgical instruments are invaluable for this sort of work—particularly the angular keratome, an eye instrument which is, in effect, a miniature triangular trowel set at an angle at the end of a thin handle (No. 3 on page 348). It is made in three sizes, the smallest of which is the most useful. This instrument should be of the best tempered steel, and before it can be used the two edges of the blade, especially the left-hand one, must be ground and sharpened to a keen cutting edge, all or most of the bevelling to be done on the top side in order not to interfere with the flat, trowel-like undersurface. Any type of plastic material may be applied with this, pressed and worked into the spaces, smoothed, and then, provided the edge is keen, sliced off level with the paint film while it is still in a plastic state. The instrument has been described in so much detail because it serves a number of other useful purposes in the studio or workshop. The smoothing of a sticky or tacky material with palette knife or any other flat instrument is often made easy by dipping the blade in some liquid: water, alcohol, or the copaiba mixture.

Repainting

Before touching up the blank areas of gesso patches, these highly absorbent spots must be treated with very thin shellac carefully applied with a finely pointed brush until the surface shows an incipient gloss; otherwise the absorbent dull spot will persist after repainting and even after the varnishing of the picture. Applying the shellac before the plug is thoroughly dry may cause it to crack. If tempera repaints are used to touch up such spots in an oil painting, they should be sized with damar in order to give them the same resistance to absorption of varnish as the rest of the picture has. The oil-putty type of plug does not require this treatment.

Obviously the new painting material must not turn yellow, or rather, it

should accompany the rest of the paint film in such changes as are likely to take place, and here the restorer must judge for himself. An average, fairly new oil painting may be matched in this respect by squeezing oil colours on to unglazed paper which will absorb the excess oil, and then mixing them with one of the glaze mediums (page 162). When tempera colours are used, there will be little or no change with time, but the restorer must know exactly how the colour is going to match when dry. Some restorers paint one approximate coat in tempera and a second or glazing coat with dry colours mixed with non-yellowing glaze medium. A great many methods suggest themselves.

A patch can seldom be made to match with one coat, even when this is stippled on carefully so as not to run over the edges, because of the difference in the colour of the grounds, and other optical circumstances. If the colour is first matched approximately, preferably keeping on the light side, it will generally be found that a second coat can be made to match the picture exactly. Some of the manipulations described under *Glazing* are useful for this work.

In all operations of the type just discussed, the object of the restoration must be taken into account. Curators of valuable collections sometimes desire the restoration to be unnoticeable when the picture is viewed in the ordinary manner and at the same time easily distinguished from the original work when examined closely; in other cases the blemishes are required to be entirely concealed. Repaints are also mentioned on pages 330 and 347.

Published Instructions. Some writers on the conservation and restoration of paintings are given to making statements which are more or less true in a general way, but which may be wrongly interpreted and often lead to misunderstandings.

A good many solvents and mixtures have been recommended as materials which will dissolve and remove the varnish and dirt from old paintings without dissolving the underpaintings; others are condemned because their action is so violent as to remove everything at once.

As a matter of fact, there is no universal, fool-proof liquid whose action is selective enough to remove varnish and automatically stop at the colour layer in all cases; some are merely more amenable to careful expert manipulation than others. In other words, these recommended solvents should be described rather as being more useful than the others to the expert worker in his efforts to remove only the top layers of old varnish, leaving the colour coat undisturbed (preferably, in the average case, with a minute trace of old varnish still adhering to it). The more violent solvents are those whose solvent action happens to be of such a nature that they will not respond to such expert handling but will continue to remove everything with which they are brought into contact, too rapidly to be controlled by the special technique the experienced picture cleaner has developed.

The behaviour of volatile solvents is purely mechanical, while that of water solutions such as soap or mildly alkaline compounds usually involves chemical action. Sometimes writers who warn against skinning a picture

will recommend such water solutions, but their effect is almost certain to be the entire removal of all traces of the varnish. In fact, as a general rule, they come closer to being automatic or selective solvents than the alcohols or ethers; but after they have destroyed the old varnish film, skinned the picture, and stopped short of picking up colour, they will immediately begin their less apparent destruction of the oil paint film, attacking it chemically so as to make it weak and spongy, altering the colour effect by causing a sort of permanent bloom, seeping into cracks and destroying the adhesion, etc.

The mistake of assuming that a faulty condition under discussion is the sole defect of a painting and thus ignoring the existence of complications which would contra-indicate the proposed remedy, has been referred to previously.

Theoretically sound materials, such as colours ground in pure damar varnish, are often recommended without taking into consideration the obstacles to manual execution which are involved and which are sometimes very difficult to overcome.

Floating Signatures. Writers on the authentication of old pictures refer to a test of the genuineness of a signature. When the painting has been signed by the original artist the signature will usually be part of the paint film; when the signature has been applied at a much later date over the varnish, or in paint of different or much newer materials, it is said to be a 'floating signature'. When a solvent is applied to such a picture, dissolving the varnish but not removing any paint, it can readily be discovered whether the signature was painted along with the picture in the same materials or whether it was added later.

Obviously, certain conditions must be taken into consideration: it can easily be understood that in some instances even a floating signature may be genuine; but in the great majority of cases, particularly when there are other reasons for suspicion, it is taken as conclusive evidence of fraud.

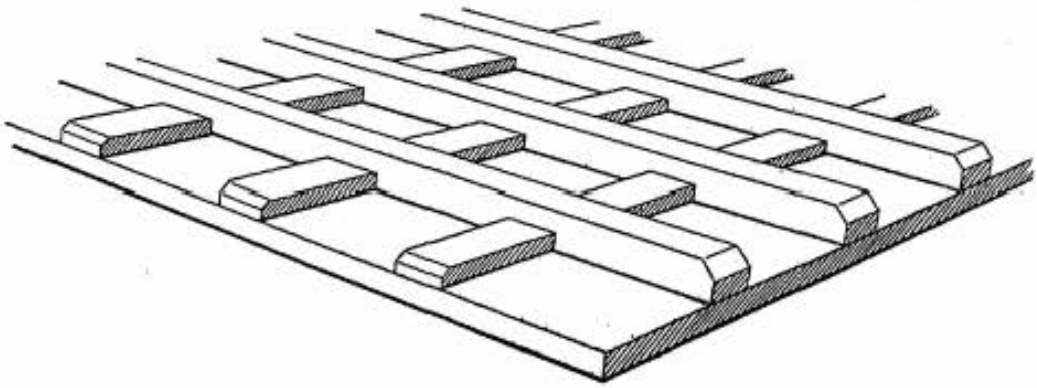
A restorer as such is less concerned with this aspect of floating brush strokes than with the problem of their preservation. While it is often necessary to remove fraudulent or undesirable overpainting and signatures, and while this work calls for considerable skill, understanding, and a comprehension of what is to be expected in the original underpainting, so many unorthodox methods have been used in painting that the restorer is often called upon to preserve legitimate floating brush strokes which will be considerably more affected by solvents than the rest of the painting.

Among examples of this sort of painting are the fine lines of the rigging of ships, which in some instances seem to have been ruled with a fine brush or pen over an isolating varnish, and delicate touches, scumbles, and glazes on portraits, clouds, foliage, and water, which have been applied over an isolating varnish so that free work and corrections would be possible during application without danger to the underpainting. The use of megilp, the addition of resin to oil colours, and other unorthodox or experimental techniques on the part of the original artist, offer complications which present themselves suddenly during cleaning and which serve to reinforce the rule

that paintings of any value should be restored only by highly qualified and experienced workers.

Cradling Old Panels

When the wood of a panel picture splits, warps, or is in danger of this type of disintegration, it is made sound and permanently conserved by cradling, that is, by gluing crisscross strips of wood to its back under pressure so that not only is the condition remedied, but the panel is strengthened and preserved against future decay. Like many other procedures of its kind, this is simple enough in theory, but must be executed in an expert and conscientious manner; if a specialist is not available the actual work may be done by any competent cabinet maker, amateur or professional, but the decision as to whether or not the panel should be cradled, and if so, to what extent, should be made by an experienced person. Most old panels are improved by cradling, but some have been injured by further complex warping and splitting despite being cradled.



The method consists of gluing mahogany or oak strips, about $\frac{5}{8} \times 1\frac{1}{4}$ inches, to the back of the panel, laying them on edge, about two inches apart for the average panel, and parallel with the grain of the wood, which usually runs parallel to the long sides of the picture. A strong hot glue or casein adhesive is used. At intervals of the same distance that separates these strips, they are slotted so that the cross strips can lie flat against the panel. These cross strips are not to be glued down, but must be able to move when the panel contracts or expands. They are usually about half as high as the strips through which they run.

The panel must remain under the pressure of clamps during the setting of the glue; in order to insure firm setting, it is usually left in the clamps several days longer than is usual in adhesive procedure. Regardless of how the method is simplified or altered, as in the case of works of minor value, by diminishing the number of strips, making them wider, etc., it should always be understood that the cross strips are not to be fastened; otherwise, more serious splitting or buckling will take place. Sometimes new panels of thin wood are cradled so that they will resist conditions they may be called upon to endure.

The cross strips, which are laid flat, may measure about $\frac{1}{2} \times 1\frac{1}{2}$ inches; the dimensions of both kinds of strips are subject to much variation, according to conditions. Formerly the prime consideration was a flat, neat-looking job; present opinion is that the stationary strips should be rather high to insure rigidity.

It has also been suggested that thin panels be mounted on heavy plywood panels on the theory that the thicker the support, the less effect warping will have on the picture. I do not know of any record proving the value of this over a period of years. Contrary to popular opinion, the complete painting or varnishing of back and edges to prevent absorption of moisture is not always advisable, as it may encourage dry-rotting of the wood; the end grain at least should be left uncoated so that air has access to it. As in other conservation procedures, a complexity of defects will sometimes result in conditions that demand special treatments. Very thick panels may be planed down; severely warped panels must be put under pressure carefully and gradually; a decrepit condition of the paint and ground layer often creates additional complications.

Wood worms or beetles in panels and furniture are easily destroyed by the application of carbon bisulphide. This is a much recommended material, the vapours of which are non-injurious to paintings, but its actual contact with paint is to be avoided, as it is a powerful volatile solvent. The technical grades have a disagreeable odour, which, however, is non-residual; the pure or C.P. grade is less unpleasant. The material is inflammable, but a mixture of 20 parts with 80 parts of carbon tetrachloride is non-inflammable. The carbon tetrachloride has considerable toxic action in this case and is not entirely a diluent.

Varnishing Pictures

The application of a thin, uniform, flawless coat of varnish, especially on a smooth old painting, is not the easiest process connected with oil paintings. Varnishes are best applied with a spray-gun; because they are comparatively thin liquids and do not need much air pressure, inferior machines are often used, but best results are obtained with a high-class modern gun which will deliver a well-atomized, fan-shaped spray. Some of those in use for industrial lacquer-spraying have traps to prevent condensed moisture or dirt from the air-source from mixing with the varnish. Most varnishing, however, is still done with brushes.

The optical effect of a heavy, glassy coat of varnish is not desirable in the light of present standards of taste, and the thinnest film that will produce a satisfactory, uniform surface is in accordance with the most correct practice from every viewpoint. A heavy coat of varnish is actually less durable than a normally thin coat and is more subject to various forms of decay. Also because of its contraction upon drying, a heavy coat applied over old or weak paintings is liable to cause eventual damage to the underlying paint which it is designed to preserve.

Varnishing is best done in a warm, dry place. Clear, windy days are best; humid or muggy days in midsummer are worst. In cold weather, varnish, brush, and picture sometimes require enough warming to take the chill out of them. The varnish is diluted with its solvent to exactly the proper consistency for best results (determined by experience, or, if it is a new material, by experimental trial). The brush should be a wide, flat bristle varnish brush of the best quality obtainable; uniformity or symmetry of thickness and freedom from shedding bristles are the two principal requirements. Some experienced varnishers prefer a softer brush, and use one of oxhair or red sable. Some prefer a rather thick brush, while others cannot get one thin enough. The thin or sparse brush is perhaps better, because it will not deposit such thick laps at the edges of the strokes; furthermore, it seems to do better work with less effort. If I were to have a special brush made either for varnishing or for applying gesso, it would be a three- or four-inch regular artists' flat bristle brush, possibly somewhat thinner than the average 'flat', but of about the same quality, and with the same incurving ends. These are largely matters of personal preference; varnishing is essentially an operation for which one must acquire the knack, and the tools are of secondary importance. Recommendations as to how to brush out a thin coat of varnish or flow on a heavy one, are similar to the previously criticized instructions for restoring, in that conditions vary so much. The following procedure may be entirely opposed by those who prefer other techniques.

The brush is dipped completely into the varnish once and then, depending upon one's experience and judgment, both sides of it and sometimes the edges are wiped off on the edge of the container so that just enough varnish remains in the brush to deposit a film of the desired thickness across the picture for 1 or 2 brush widths. After the varnish has been spread over part of the picture, or, in the case of a small picture, over all of it, a second application of the empty brush is made all over with a short, back-and-forth wrist motion in order to work the varnish well into the canvas weave; then a rapid single-stroke one-way brushing is done at right angles to the previous brushing to distribute the varnish more equally and to minimize laps in the first stroking; lastly, there is a straight, extremely light, rather slow brushing in the original direction with the brush held very flat, as a finishing or smoothing manipulation.

In our modern cities it is seldom possible to work in a dust-free atmosphere unless a specially constructed and air-conditioned room is available, and the warning to guard against dust as much as possible will be anticipated. After the varnish on a painting has dried for about ten minutes or as long as it takes for it to become set so that it will not run, the picture may be leaned at an angle, face against the wall, to finish drying. There may be some circulation of air, but no direct draughts. In a reasonably clean place there will be small danger of the picture's acquiring much dust in this position; coarse dust will not settle upward, but a swirling current of air might carry it upward against the picture.

It is not possible to apply a brush coating of varnish to a painting in a

vertical position without sagging or frilling of the varnish; the defects known as curtains, tears, streamlines, etc., are practically unavoidable. However, pictures can be so varnished by an expert use of the spray-gun, provided one is thoroughly familiar with the particular varnish being used, and is able by the correct spraying manipulations to avoid the above-mentioned defects as well as the unpleasant 'orange peel' effect which sometimes results. Toch[102] has devised a method of making balls of absorbent cotton covered with well-washed old lint-free sheeting, dipping these into a dilute varnish, and applying an even coating to a painting in situ, as French polish is applied. Usually only one very thin coat may be thus put on, and it does not take well on all types of paintings. The varnish recommended for this purpose is damar in turpentine plus 10% of stand oil, thinned down considerably with a mixture of half turpentine and half mineral spirit. This treatment is most effective on paintings which are in fairly good condition, where the greatest defect is a dulling or blooming of an otherwise intact surface.

As mentioned under *Varnishes*, damar is first choice as a picture varnish; mastic is easier to apply in a flawless coating but will turn yellow and is more likely to bloom. None of the other materials so far developed are in a class with these two. Flat (mat) finishes should be tested for yellowing, for non-polishing when rubbed, and for streaky or greyish effects on dark or deep-toned paintings. Pyroxylin (cellulose) lacquers and industrial varnishes made from synthetic resins contain a variety of oils and plasticizers; they become brittle and lifeless with age, turn yellow, and are too far removed in general properties from the materials used in the average oil or tempera painting. Perhaps their greatest disadvantage is their insolubility in the normal painters' solvents; most of them require the paint-remover type of solvent and therefore present complications both in application to and in removal from paint films. Some modern synthetic varnishes which can be freely thinned and dissolved with mineral spirit or turpentine have recently been placed on the market. Their behaviour is generally satisfactory when subjected to laboratory tests; more complete confidence may be placed in them after their composition has been studied and they have had a little more use under actual painting conditions. (See page 151.)

Removal of Bloom from Varnished Paintings. As mentioned in the discussion of varnishes on page 143, a mild surface bloom is not a serious or permanent defect when it occurs on a well-varnished painting. It may be removed from a picture which is well protected by an unbroken film of varnish by placing a few drops of light machine oil (such as is sold in small oil-cans for household use) on a flat folded Kleenex tissue and rubbing the picture's surface with small circular and back-and-forth strokes, using as firm a pressure as the canvas will take without injury. The oil should remove the bloom immediately, but satisfactory technique calls for evenly distributing the smallest possible amount of oil on the surface, and rubbing should be continued until all excess oil is absorbed back into the tissue. Certain types of cloth may also be used; a soft, coarsely knitted cotton generally known in house-furnishing departments as an absorbent floor cloth works well, but

some experimenting is necessary before using untried fabrics; the requirements for such a cloth are that it should not scratch the varnish or deposit lint, and that it should absorb and retain excess oil. If one doubts the quality of the prepared oils on the market, a satisfactory material can be made by mixing six parts of de-bloomed paraffin oil with three parts of olive or rapeseed oil and one part of highest-quality kerosene. Although these materials do not affect a varnish film, they must be used with discretion and never applied to a cracked paint film which is not thoroughly protected by an intact coat of varnish, or to an unvarnished painting, because the oil might cause damage if it were allowed to soak into the canvas or paint. Freshly applied varnish must be thoroughly dried, preferably for several weeks, before such treatments are applied.

Photographic Records

All works of art should be photographed before and after any extensive cleaning, repairing, or restoring. Such photographs should be made in a professional manner and care must be taken to record the exact extent of the original damages, not exaggerating them, but at the same time making sure that the camera does not minimize them; in other words, the actual condition as observed on close examination should be depicted. In the case of important works, it is often necessary to make more than one photograph for this purpose: sometimes it is desirable to have a close-up of some unusual defect or a detail of the varnish or some other surface effect (that is, focusing on the surface of the film to show the condition of the varnish), as well as a deeper view of the actual picture disregarding the surface.

The record of the finished restoration should be made under identical photographic conditions (as to camera, film, lighting, and development) if it is to have any value for comparison purposes, and no attempt should be made to conceal blemishes which may purposely or unavoidably have been left in the finished work.

Framing Pictures

The universal habit of fastening canvases into frames with nails is not a good one; when the nails are driven into the stretchers at an angle so that their points enter the frames, it is a clumsy and difficult matter to remove them, and both stretchers and frames are often spoiled during the procedure. Driving nails halfway into the frames and bending them over the stretcher does not always hold the picture securely; also the nails are likely to scratch or damage other pictures and frames with which they may come in contact.

Small strips of brass called brass mending strips, measuring about 2 inches long and ½ inch wide, with a screw hole at either end, are obtainable in well-stocked hardware and chain stores. If an end of one of these strips is screwed to the frame with a half-inch brass screw, the end which extends over the stretcher will hold the picture in place securely and neatly; four,

six, or eight of these strips may be used. They are flexible enough so that if the stretcher is not flush with the frame, as is usually the case, they may be bent in such a way that the end which goes over the stretcher will lie flat and fit snugly. A screw can also be placed in the other hole so that the strip is fastened to the stretcher as well as to the frame, but this is not usually necessary. If brass strips are not rigid enough for some large pictures, iron ones can be used. Pictures can be removed from such frames and replaced any number of times without wear or damage.

Pictures on wooden panels will warp when improperly framed. If they fit into the frame too snugly all around there will not be sufficient room for expansion, and they may buckle and split. If they are not well braced in a strong frame, they will (unless they have been cradled) be subject to erratic warping. Two or three thin pieces of cork, slices from a bottle cork, placed along each edge of the picture and secured to the frame with small brads, can be arranged so they wedge the panel into the frame tightly; their resilience will take up any expansion or contraction which may occur. When the brass strips are used to fasten panels into frames, they should be bent so they press the panel firmly against the rebate.

One way of holding a thin panel securely and permanently in a frame is to drive double-pointed nails one-third of their length into the edges of the panel at frequent intervals. Cut and mitre the ends of four wooden strips, of the same thickness as the panel, so as to form a rectangle, the inner measurements of which are somewhat larger than those of the picture. These strips are affixed to the edges of the panel with the double pointed nails, each nail penetrating about one-third of its length into the strip and about one-third into the edge of the panel. The frame formed by the strips is then securely attached to the picture frame, which must, of course, have a wider rebate than usual. I have seen an American portrait on a thin fruit-wood panel framed in this manner, in perfect shape after more than a hundred years of storage under the most severely adverse conditions, where other panels had suffered badly.

Cleaning and Repairing Pictures on Paper

For this type of work an understanding of the properties and characteristics of paper and the nature of the materials which compose the picture is essential. Prints (the term being used here in the narrower sense, meaning pictures made by the customary offset or type-printing methods), etchings, lithographs, and line engravings, whether in black or in colours, are made with oily inks and can be wet in water without injury; therefore the easiest way to perform such operations as are required in cleaning and bleaching them, is often to immerse them in trays of water or solutions. It is needless to refer to the fragility and sensitivity of such pictures, particularly old ones, when they are wet, and it should scarcely be necessary to point out the care and delicacy with which they must be handled during operations; for this reason more than the usual attention must be given to order, system, and

convenience in the workroom, implements, and apparatus. Print papers, unlike the papers described under *Water Colour*, often contain a number of ingredients such as fillers, coatings, and extra amounts of size, added to impart desirable qualities.

There are a number of details of precaution to be observed. Many have been omitted here; some are analogous to those given in connection with the treatment of oil paintings; and others will be obvious to the intelligent worker. The best teacher of careful manipulations is a varied experience; worthless prints of considerable age are easy to obtain, and experiment on them is simpler and can be carried out more systematically than is the case with oil paintings.

Large trays of glass or acid-proof white enamel, such as are used by photographers, are employed; the wet paper is handled by placing under it a sheet of plate glass somewhat larger than the picture, but smaller than the tray or tank. When this is lifted from the bath the picture adheres to it, and after the liquid has drained off, blotting paper is carefully used to remove excess moisture, and the paper is allowed to dry on the glass. An adequate supply of largest-size white blotting paper is a necessity; also a set of smooth drawing boards, cardboards, or Presdwood in various convenient sizes. Wooden or metal screw clamps, flat, wide camel-hair and hogs-hair brushes for paste and for washes, a wide rubber roller, sponges, tweezers, etc., are a few of the miscellaneous articles indispensable in this work; others will occur to the restorer. A sink or tub with running water and a small rubber tube attachment are also essential.

The resistance of printing ink to water and to chemical solutions, and the apparent recovery of the paper after its wetting, must not lead one to suppose that such treatment may always be carried out without danger. The sizing with which many papers have been prepared may be entirely or partially washed away and may have to be replaced before retouching or restoring can be done; some papers are made of two or more plies or sheets of paper pressed together; these will sometimes separate or at least blister when immersed in water. Should such multiple sheets become blistered or partially separated, a prolonged soaking in a tub of water will generally allow one to strip off the extra plies, and the thin sheet with the picture may be remounted on good drawing paper or cardboard. It should be superfluous to add that in all such separating operations, including the removal of old mountings from prints, etc., two layers should never be forcibly pulled from each other; no separation should be attempted until the paste or glue has been dampened to such an extent that the layers will come apart easily and with no trace of any damage to the fibres of the valuable layer.

Some Japanese prints, as well as some artists' proofs of coloured block prints, monotypes, etc., are made with aqueous paste-colours instead of with the more usual oily ink, and cannot always be immersed in water with safety; but they will usually stand a limited amount of cleaning if it is carried out correctly.

Cleaning and Bleaching

The first procedure in cleaning prints is to remove oily or greasy stains, if any, by applying a volatile solvent with absorbent cotton or a soft brush. Acetone and diacetone are good solvents, but according to the nature of the stains other solvents may be required. Carbon tetrachloride and petrol are the best wax solvents. Occasionally prints may be completely immersed in solvents if a cautious testing shows that their lines or colours are not affected by them. Those who are not familiar with the use of volatile solvents are advised to note their individual properties and the precautions to be observed in handling them, as discussed in the section devoted to them beginning on page 262.

According to Scott,[96] the best material for removing linseed-oil and paint stains of long standing is pure, colourless pyridine applied with a brush of glass fibres. Repeated applications, followed shortly after by removal of the liquid with blotting paper, will often either remove such spots or diminish them to such an extent that they are made inconspicuous. The print is allowed to dry until the odour of the pyridine has disappeared. Ordinary impure pyridine is a yellowish liquid with a highly disagreeable odour; it is used as an alcohol denaturant.

A coat of simple-solution varnish can usually be removed by immersing the print in alcohol, scrubbing it gently with a camel-hair brush while in the bath, rinsing with fresh alcohol, and drying. Weak ammonia water is also sometimes useful for this purpose. Oil or oleoresinous varnishes are seldom applied to prints; when they have been used they can seldom be removed without leaving blotchy remnants. Superficial dirt, pencil marks, etc., are removed with Artgum or soft bread pills.

The customary method of bleaching, cleaning, and removing common foxing or brown stains which resemble iron rust (but which are usually a species of mould), is to immerse the print in alternate solutions of bleaching powder and hydrochloric acid, the strength of these solutions to be kept dilute so that they will not harm the paper. The report quoted above recommends a ½ to 1% solution of bleaching powder, which will be ¼ to ½ ounce of powder to a quart of distilled water, and 1 fluid ounce of C.P. hydrochloric acid to a quart of water.

Many accounts of this process were published in a rather unscientific manner during the early years of the twentieth century; some writers recommend bleaching powder, others recommend concentrated ready-made solutions of both calcium hypochlorite and sodium hypochlorite, or Javelle water, which act alike. Another similar bleaching solution which has about the same action is Milton. The best procedure, taking into consideration the results, safety to the paper, and ease of control, is the following:

The print is immersed alternately, first in the acid and then in the bleach for 10–20 minute periods, until clean or until no further lightening is apparent, after which it is washed in running water for an hour or two. The print is handled on plate glass, as was described earlier; while wet it is very fragile.

Bleaching powder is popularly called chlorinated lime or chloride of lime, and is sold in a sufficiently pure grade in domestic stores; instructions for making Javelle water are printed on the containers.

Another bleaching process is the following, recommended by J. G. Goulinat;* it uses an oxidation-reduction reaction familiar to all chemists. The figures refer to grams of material and millilitres of water.

Immerse the print in a 5:1000 solution of potassium permanganate for several minutes; remove from tray, rinse off with water, and return to the permanganate solution to which has been added a 10:1000 solution of sodium thiosulphate (hypo); allow to soak for 10 minutes. Then add 10 drops of C.P. hydrochloric acid. When print is white, wash in running water for ½ hour, and dry. The print is handled on plate glass, as noted above. The action in this process is harsher and more drastic than that of the chlorinated bleaches. Exposure to sunlight, as recommended for oil paintings, is efficient, but is likely to fade some of the more fugitive inks and colours.

For applying bleaching action to pictures which will not withstand immersion in solutions, and particularly for restoring the original whiteness of high-lights and other spots on a drawing which has been touched up with white lead water colour, a recommended procedure is to make a flat plaster of Paris cast or tile, and after impregnating the porous surface of this with peroxide of hydrogen, to arrange the drawing or print with its face down ⅛ inch or so from the cast, whereupon the darkened areas are bleached in a few hours by the action of the peroxide. The same method may be used to treat other bleachable conditions. When the drawing or print is so sensitive to water that even moist vapours such as these will cause ill effects, as in the case of fragile mounted or unmounted India-paper prints, an ethereal solution of hydrogen peroxide is recommended. Ether is shaken with peroxide solution in a bottle, it extracts the peroxide from the water solution and floats on the top of the water in a well-defined layer. (See remarks, page 269 for, precautions in handling ether.) In connection with this procedure and with direct applications of hydrogen peroxide solution to paint surfaces which are partially but not entirely resistant to aqueous solutions, it has been found that the destructive effect of water is greatly diminished by addition of 50% of pure ethyl alcohol to the solution. Hydrogen peroxide is universally obtainable in 3 to 4% solutions, and also in a powerful 30% solution called Superoxol, which requires careful handling, as it attacks the skin.

Another method which is sometimes found effective (and one which does not appear to have been published) is to allow the fumes of a strong reaction of concentrated bleaching powder and acid to come into contact with such spots. A small swab of absorbent cotton fastened to a wooden applicator is dipped into rather concentrated hydrochloric acid (1:1) and then into a dish of dry bleaching powder, particles of which will adhere to it. While the fizzing reaction is still going on, the cotton is brought close to the darkened spots, whereupon the fumes effect rapid bleaching. The same materials may

* In the article, 'Paintings, Restoration and Preservation of,' in the *Encyclopædia Britannica*, 14th Edition.

be applied over a flat surface as in the preceding method, except that in this case glass instead of the acid-soluble plaster must be used.

Writing-ink stains are removed by the bleaching-powder process, which is the basis of most of the prepared ink eradicators. A more powerful remover of inks and similar stains is oxalic acid, a 10% solution of which may be applied with a glass rod. However, the application of chemicals without subsequent immersion in or thorough washing with water is not to be recommended; chemicals left behind in the paper weaken it and cause eventual staining. After every chemical treatment paper should be well washed in running water in the same way in which a photographer washes his pictures, and for the same reason.

Prints in storage will absorb atmospheric moisture, which is nearly as great an enemy to them as it is to oil paintings. Authorities on the conservation of prints consider it very important to sterilize them after the removal of mould marks. This is best accomplished by subjecting them to the vapours of thymol by placing them in a tight cabinet which contains a dish of thymol over the heat of an electric light bulb. The material is volatilized by allowing the light to remain on for two hours, after which the print is left in the cabinet for 24 hours longer. The procedure can be repeated as often as necessary without harm to paper or vellum, but printed surfaces may sometimes be spoiled by the solvent action of the fumes. This process, which is described in detail by Plenderleith,[103] does not give permanent protection against further infestation.

Antiquated recipes often recommend restaining the brilliant white paper of a cleaned print with solutions of tea, coffee, ale, tobacco, etc., or smoking it over a damp wood fire, in order to bring it back to a 'natural' aged appearance —a procedure not in accordance with modern practice or taste.

Very fragile pictures, prints on India paper or Japanese tissue, and pictures done in soluble or sensitive line or colour which will not withstand immersion, may be treated from the rear by pressing upon them blotting paper impregnated with the solutions, or may be pressed between two nearly dried blotters. The disadvantage of this procedure is that only partial results are effected and badly blemished prints are not well cleaned or bleached; however, in some cases little else can be done.

Pastels. The restoration of pastels requires delicate operations. As noted under *Pastel Painting*, they will survive a limited amount of pressure in contact with glossy paper or cellophane so long as there is no lateral movement, but every precaution should be taken to avoid rubbing their surfaces. A layer of dust can often be removed with a blast of air, and I find that sometimes, but not always, a careful light contact with a sheet of paper coated with a very slight, well-dried film of rubber cement will result in the dust's being picked up without too much removal of colour. Tears can be plugged by mounting the picture, cutting out a patch from paper of the same thickness and texture, and proceeding as in the case of canvas plugs for oil paintings. These patches can be tinted with water colour before being coated with pastel; all repainting and matching of colours will require very careful preliminary

selection of crayons and usually the manufacture of special shades. It is not a difficult matter to retouch and smooth out blemishes if one has learned the manipulations of applying pastel, and with a picture that has been done in an average good thickness of colour (as the early portraits usually were), minor spots can often be smoothed out with a delicate handling of a leather stump.

Beaufort[99] recommends cleaning and bleaching a pastel by taking it through most of the operations to which prints are subjected, from the rear, carefully floating the picture on the surface of the solutions and the water, if necessary attaching its edges to narrow strips of thin cork with drawing pins. A sheet of strong drawing paper is used as a support in place of the plate glass, and after a preliminary floating on water to remove creases, the print is picked up with the drawing paper and floated for a few minutes on a very weak solution of Javelle water or other single-solution bleach. As a final treatment, the pastel on its drawing-paper support is placed in a tray and its surface gently flooded with water for a few moments, after which it is removed and carefully dried.

Water Colours. As water-colour painters know, the average completely dried water-colour painting will withstand a careful and not too prolonged rinsing in water provided it is not rubbed while wet. Bleaching coloured pictures or pictures on coloured paper is not to be undertaken thoughtlessly; many colours and coloured inks, especially the older ones, are susceptible. Retouching of mended water colours is done with weak colours in a stippling manner with the point of a small, nearly dry brush. In the case of any picture on paper, when the sizing needs replacement for purposes of retouching, a very dilute solution of gelatin is best—a half-ounce or less to a gallon of water.

12

Miscellaneous Notes

Notes on Perspective

The surface of a picture is a plane figure of two dimensions bounded by the frame, and any lines or masses depicted upon it lie within that plane and have only length and breadth. Aesthetically, a two-dimensional picture or design may be entirely successful, but the development of most schools of art has led to a demand for perspective or a means of creating upon a two-dimensional surface the effect of three dimensions.

Perspective in a picture is a sort of optical illusion perceived by virtue of training and education and made possible by certain mechanisms (sometimes called defects) of the human eye. It is therefore an artificial system evolved for the purpose of creating an effect, and as such it must follow arbitrary rules and laws.

The rules of our system of perspective apply principles which have been worked out by geometry; however, exact perspective as studied by mathematicians is not strictly applied to the usual pictorial technique, but only such basic points as are of practical value. Writers on the subject have always gone to great lengths to point this out and to make the artist aware that according to his artistic intentions he must consciously decide for himself just how far the construction of his drawing should follow mathematically produced points, and just where these points should serve as guides for selective approximations, so that the result may be the work of his own hand and not an example of applied mechanics.

The present account is a short outline, for reference purposes, of a few of the basic geometric constructions, selected for their simplicity and practical application; for a more thorough study, the reader is referred to the complete manuals on perspective, where the relationship of these basic rules to artistic purposes is shown.

Application of Perspective to Pictures. A defect of our system of perspective from the mathematical point of view is that a vanishing point is really accurate only when the subject is viewed from one point or station and when the line of vision is trained directly on one point of the scene. Artists seldom attempt to secure extreme mathematical accuracy in all parts of a complex drawing; the reason for special care and accuracy in the guide lines or underpainting is that the artist may thereby guard against too great an error in perspective, the assumption being that one is necessarily bound to deviate somewhat from mathematical accuracy during creative work, and that the

more accurate the guide lines the easier it will be to keep within the bounds of acceptably correct drawing or to control deviations at will. Whether or not distortion, or departure from realistic perspective, is advisable is entirely the concern of the artist himself; but it is almost universally expected, according to the general ideas on art at present, that such effects will be deliberate and controlled rather than accidental.

Some kinds of painting are not concerned with perspective or third-dimensional relationships, but we have become so imbued with the third-dimensional feeling that it influences most of our works.

Aerial Perspective. In nature, the distant parts of a landscape assume a less brilliant colour than the objects in the foreground; they are often made hazy or given a bluish-white tone by the volume of atmospheric moisture through which they are viewed. This effect may be directly translated to a picture without the use of rules or laws other than those which can be learned by observation of natural phenomena. Other elements being equal, objects have a tendency to become cooler in colour (to move away from the

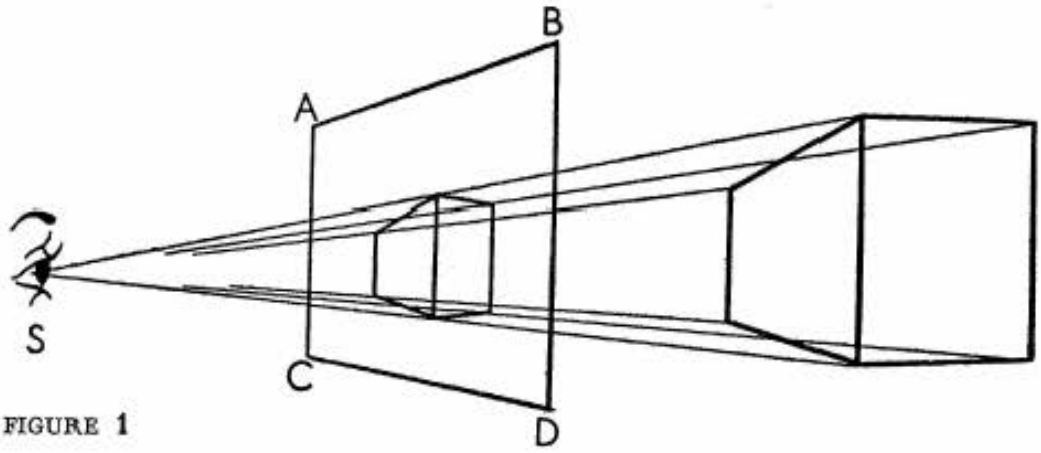


FIGURE 1

red-orange-yellow side of the spectrum and toward the green-blue-violet side) as they recede; this change may be depicted by mixing more white or pale pigment with the colours. In black and white pictures, bold contrast is used in the foreground and greys and blending tones in the distances. The Chinese and Japanese painters utilized this method of depicting recession by interposing mists and aerial softening in some of their monochrome landscapes.

Linear Perspective. We observe, in addition to these colour changes, that objects in the background appear to diminish in size as they recede, that parallel lines appear to converge, and that horizontal lines assume various angles. Depending upon our degree of skill, we are able to approximate these relationships, so that our drawings appear more or less correct according to our impressions, by the application of a geometric perspective which conforms to established rules. An *isometric drawing* is one in which each dimension of an object is represented in its actual measurement or proportion. This method is sometimes used in mechanical drawing and mathematics, but it gives a distorted view of the object, whereas a drawing in true perspective

of the *apparent* dimensions, though not in accordance with actual measurements, gives a true impression of the object as viewed.

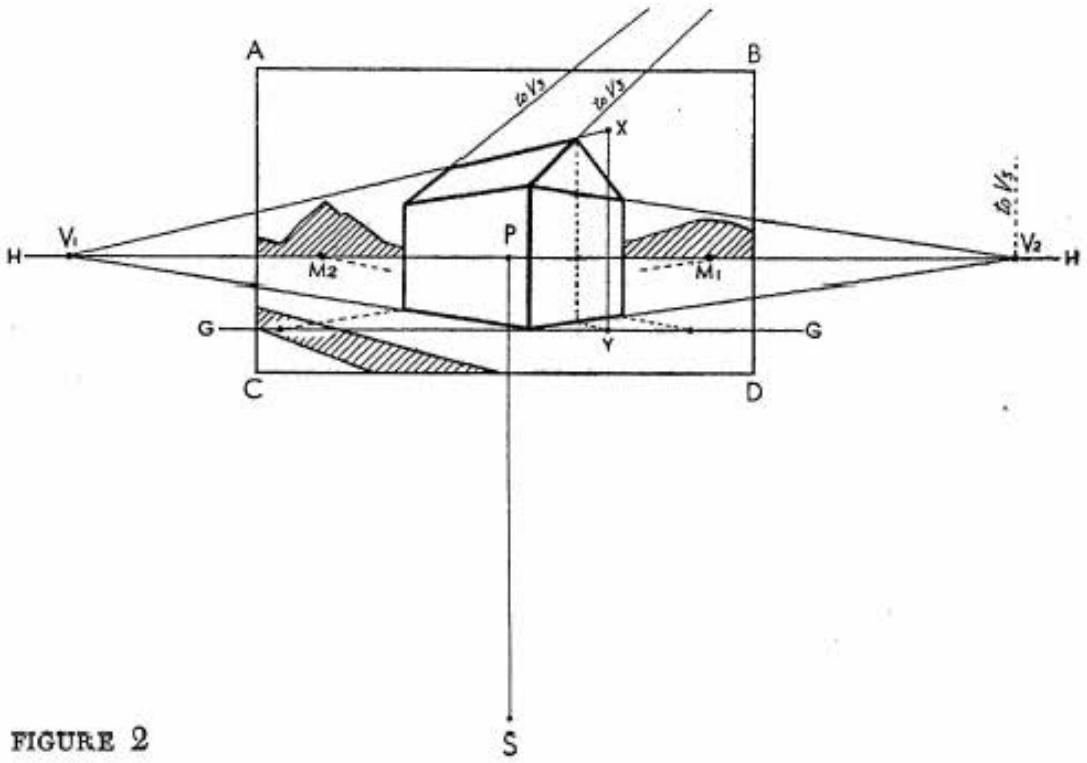


FIGURE 2

The terms used in these notes are those universally employed in reference to the construction of perspective drawings. Observer refers to the artist, or original observer of the scene; spectator refers to the person looking at the finished picture.

Picture Plane (ABCD in figure 1). An imaginary transparent plane interposed between the subject and the eye of the observer, as if it were a sheet of glass, through which the cone of vision passes, converging upon the observer's eye. This plane corresponds to the surface of the picture.

Cone of Vision. A term used occasionally in the explanation of perspective, especially when the eye is compared to a camera lens. The light rays reflected by the subject pass through the picture plane and converge upon the eye; they are depicted as imaginary straight lines which form a conical design, and they delineate the perspective points on the picture plane as they pass through it.

Horizon Line (HH). A construction line drawn across the picture plane, parallel with its upper and lower sides. In a landscape it is usually somewhere near the centre; in a sea view it would be the actual horizon; in any landscape it may vary in position, depending upon the nature of the scene and its significant objects, but it is always on a level with the eye of the observer. For purposes of perspective construction it is sometimes necessary to extend the horizon line beyond the picture on either or both sides.

Point of Station (S). The point which corresponds to the eye of the ob-

server, fixed in front of and opposite the middle of the horizon line, at a distance varying according to the requirements of the picture and the judgment of the artist. This point is normally about as close to the picture as one can stand and take in the whole view comfortably. The distance is not selected according to any strict rule, but should depend mostly upon the width of the angle of view of the subject. One traditional method is to construct an inverted equilateral triangle on the horizon line of the picture and use its apex as the station point. Another familiar procedure is to make the distance slightly less than the width of the picture. The station point is the basis of mathematical perspective. Because it is fixed, placed outside the picture plane, and accurate only when used as if a person were sighting along a line with one eye, some of the flaws of a purely mathematical perspective as applied to

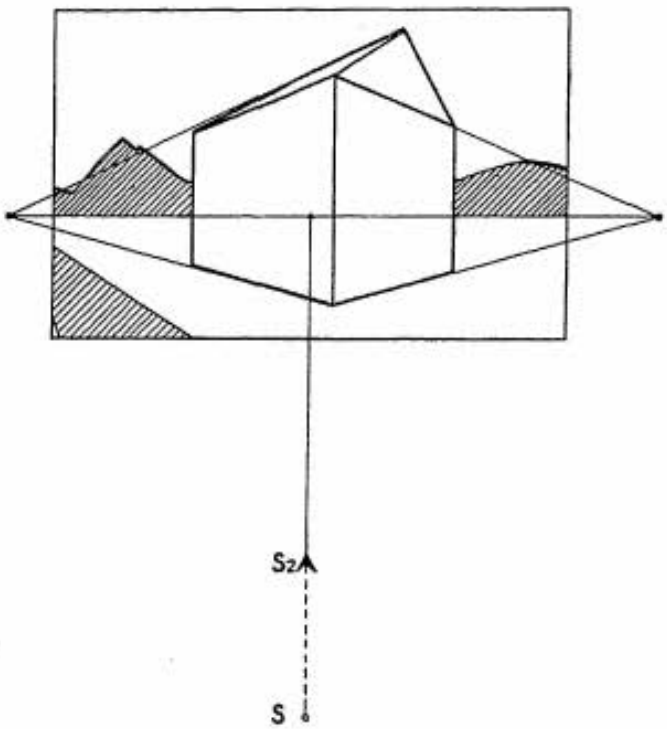


FIGURE 3

artistic purposes are evident. Almost every painting contains more than one system of lines, and spectators view it from many points. In figure 1, the eye corresponds to the station point; in constructing a drawing the artist makes a simple diagram, for convenience swinging the station point down, placing it below the picture plane, as in figure 2. If the distance between station point and picture plane is shortened, that is, if the observer moves forward the recession of background will be more violent and objects in the foreground will loom up. If the distance is lengthened, that is, if the observer moves backward, the recession will be more gradual and the scene will be flattened out. Raising this point on the diagram is equivalent to coming nearer to the subject; lowering it is the same as retreating in order to include more foreground, as the constructions which follow will show.

Point of Sight (*P*). The point on the horizon line opposite the eye or station point.

Line of Vision (*SP*). A straight line drawn from the station point to the point of sight.

Parallel Perspective and Oblique Perspective. When a side of an object is parallel to the picture plane and when the line of vision is exactly in its centre, the object is said to be in parallel perspective; when the object is turned, it is in oblique or angular perspective. Figures 7 and 9 are in parallel perspective and figures 2 and 3 are in oblique perspective.

Ground Line. The base or lower boundary of a picture plane. The term may also be applied to a similar construction line used anywhere in the

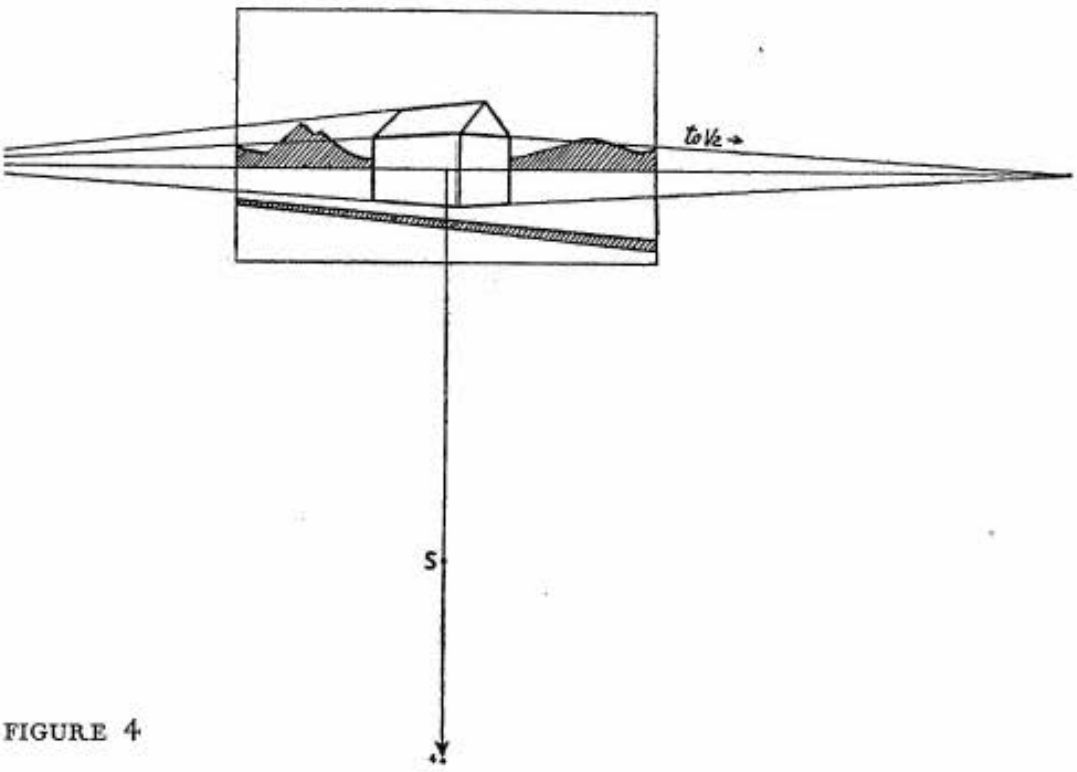


FIGURE 4

picture to measure off points or to determine the scale of a figure, in which case it should preferably be called a scale or scale line (CD; also GG; see figure 2).

Vanishing Points (V_1, V_2). The lines which lie in a plane of any single object or group of objects, if extended toward the horizon, will meet at a point in infinite distance; in a picture, the point on the horizon line where they apparently converge is called the vanishing point. Depending upon the directions in which the planes face, a scene may have many or few vanishing points. Figures 7 and 9 are in parallel perspective and therefore each has but one vanishing point, the point of sight. The other figures are in oblique perspective and have a vanishing point on either side of the point of sight. Lines above the horizon line always converge downward to it; those below the horizon line converge upward to it. Lines which lie on a plane parallel to the

picture plane do not approach the horizon line and therefore do not converge. For example, the sides and rungs of a perpendicular ladder which faces the observer do not converge; if they appear to, the line of sight has been shifted and they no longer lie on a plane perpendicular to it. Lines such as the edges of some sloping roofs and stairways do not lie in planes parallel to the horizon line in the actual scene, and their points of convergence do not lie on the horizon line but meet at a point directly above a vanishing point (V_3, figure 2), or, if downward, below it. When lines are drawn from S to the two vanishing points of a rectangular figure they always form a 90° or right angle.

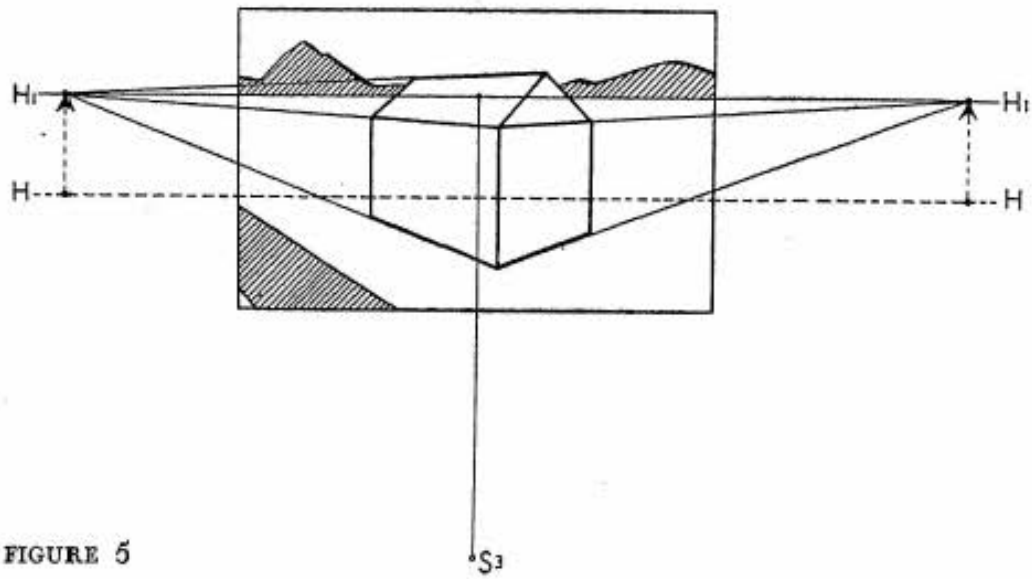


FIGURE 5

Figure 2 shows most of the construction lines and points discussed above.

Figure 3 shows what happens in this scene when the observer moves forward, raising the station point from S to S_2.

Figure 4 shows what happens when the observer moves back, lowering the station point from S to S_4.

Figure 5 shows what happens when the observer moves to a higher level, raising the horizon line from HH to H_1H_1.

Figure 6 shows the result of shifting the station point to the left.

Lines of Measurement. In order to locate the depth of objects in recession or to determine the distance between objects which recede at regular intervals, lines of measurement are used. A line of measurement is found by laying off a point on the horizon line using a vanishing point as a centre and the distance between it and the station point as a radius. A line drawn from this *point of measurement* to a point on the ground line is a line of measurement.

One of the most convenient methods for placing objects in recession is to mark off a crisscross or checkerboard pattern of squares on a ground plan or floor of the scene (figure 7). The usual procedure is to mark off the width of these squares on the base of the picture (the smaller they are made, the

more accuracy of detail can be obtained) and connect these points with the vanishing point. From the vanishing point, a point of measurement is established as described above, and the line of measurement MG is drawn to the opposite lower corner of the figure. The squares in perspective recession are then obtained by drawing horizontal lines through the points where this line intersects the convergent lines. If desired, another line of measurement may be drawn on the opposite side of the point of sight.

The line XY is the actual scale height of the objects. Some artists believe this method to be too mechanical, the recession sometimes being defective for its purpose—too sudden or too gradual—so they establish the points of measurement by trial or judgment instead of by actual measurement. If

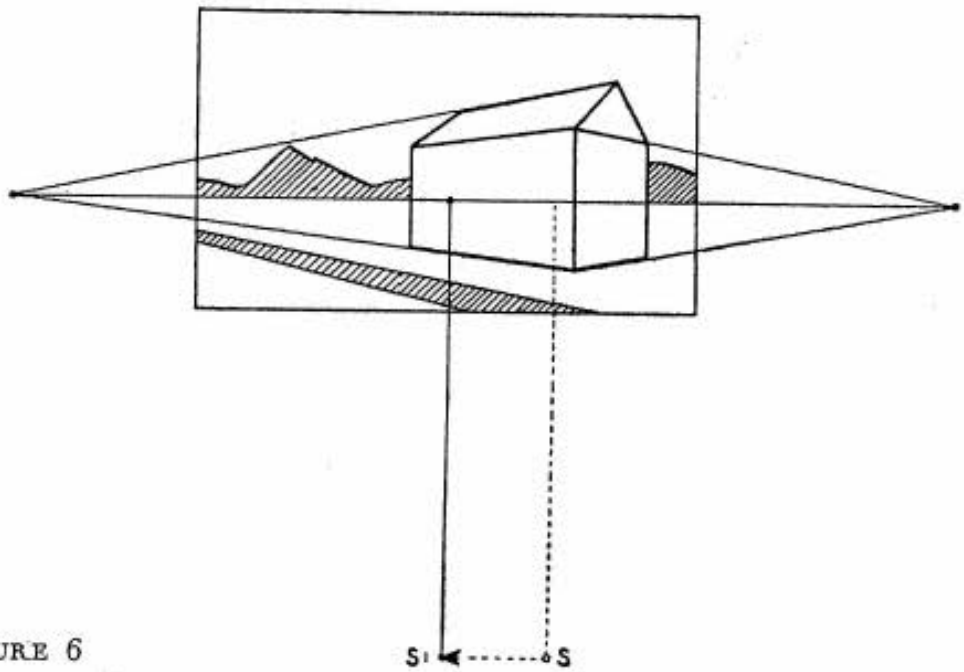


FIGURE 6

receding points are required in an area which is in oblique perspective, both vanishing points and both lines of measurement must be used and the lines of the squares are then determined by the two sets of intersections instead of being made parallel to the ground line.

Projection of a Ground Plan into Perspective. Figure 8 shows a method for the accurate projection of the ground plan of an object in oblique perspective; this method can be used when it is desired to project the ground plan in scale or proportion to actual measurements and in any size, either larger or smaller than the drawing of the ground plan. The rectangle F corresponds to the floor of the little house in the other diagrams, and the terms and principles discussed under those examples apply here.

First select the station point to conform with the direction and distance of the observer from the object. In this particular case the observer is slightly to the left and quite close to the nearest point of the object. Draw a vertical line upward from S. Draw a horizontal scale line (GG) at any convenient distance above the plane. If the object is part of a scene and it is desired to

insert it into a picture plane, the distance between d and GG will naturally have to be made great enough to accommodate the foreground. Draw a horizon line (HH) parallel to GG, and at a distance above it equal to the height of the observer's eye level, so that its intersection with the vertical line will be the point of sight (P). From S draw a line parallel to a side of the rectangle and another at a right angle to it, and use the intersections of these lines with the horizon line as vanishing points (V_1, V_2). Using these vanishing points as centres, locate the points of measurement according to previous instructions. The following basic elements of a perspective drawing have now been estab-

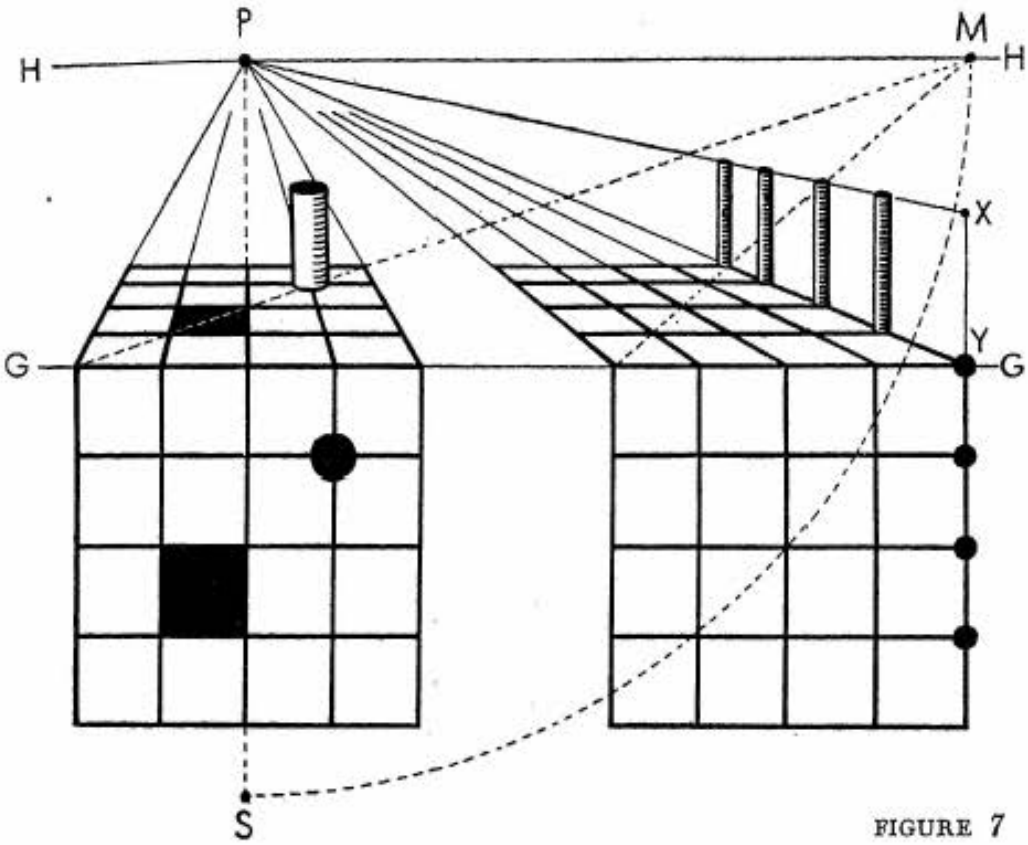


FIGURE 7

lished: station point, horizontal scale line, horizon line, vanishing points, point of sight, and points of measurement.

Draw a vertical line from the point of the ground plan nearest the observer (a) to the scale line GG, and draw lines from this point (a_1) to both vanishing points. From point a_1, lay off on the scale line the actual desired scale measurement of a–b and connect the point b_1 with its point of measurement M_1. Repeat this procedure on the other side of a_1, using the measurement a–c. From the point b_2, where the line of measurement from M_1 intersects the line from a_1 to its vanishing point, draw a line to the opposite vanishing point V_2. Repeat this procedure on the other side to locate c_2, and draw the line c_2–V_1. The rectangle a_1, b_2, d_1, c_2 is the projection of the ground plan F.

If the vertical line a–a_1 is extended upward from a_1, it will be a vertical

scale line for the object, and any scale measurement laid out upon it will establish the object's height or the height of details within its planes. A line drawn from a point of vertical measurement to a vanishing point will determine these heights in perspective. Such a line would correspond to the line XP in figure 7.

Circles and Curved Lines. The projection of curves in perspective is usually accomplished by reference to straight lines or rectangles; for example if a circle is to be placed in perspective, a square whose sides are the same length as the diameter of the circle is constructed below a ground or scale line, put into correct perspective, and the circle inscribed freehand within this rectangular shape, where it will assume the form of an ellipse. When the curved figure is more complex than a simple circle, it is sometimes convenient

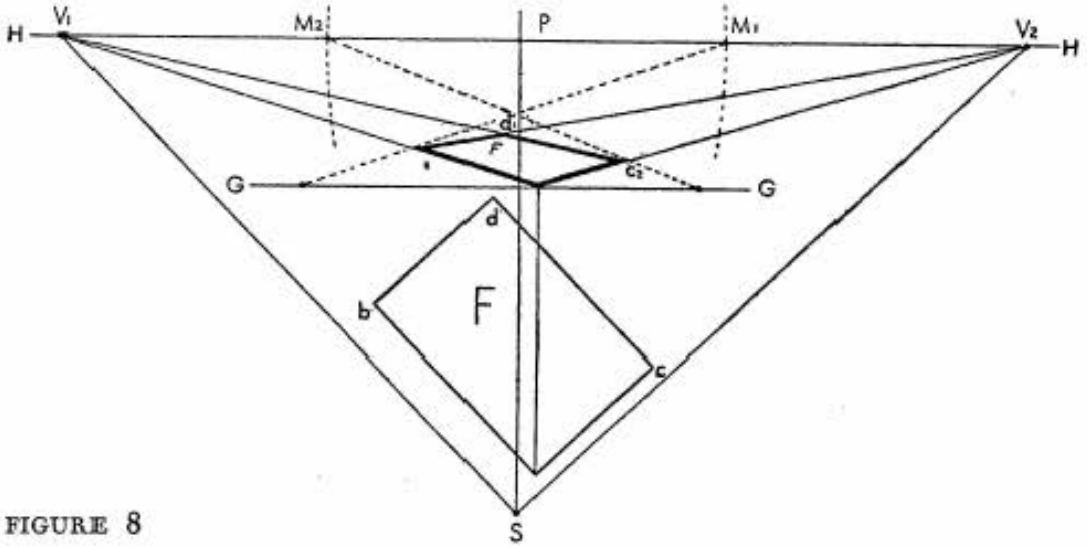


FIGURE 8

to block off the guide-figure in rectangles and refer to each section separately by an application of the checkerboard system. The final result will depend upon the skill and experience of the artist.

Sometimes it is desired to depict a circle in perspective with greater accuracy than can be obtained by drawing an ellipse freehand within the perspective square, or the circle is viewed at an unusual angle or has complexities of construction the drawing of which requires a little more guidance than that supplied by the perspective rectangle. Figure 9 is a fairly obvious illustration. One must determine the place where the forward edge of the circle in perspective is to come, and through that point draw a horizontal scale line. A square is laid off below this line, a circle inscribed within it, and diagonals are drawn upon it. The square is put into perspective by means of vanishing and measurement points, as previously described; the location of the far side of the figure is obtained by drawing a line, MG, from either point of measurement to the opposite upper corner of the square already constructed. When the perspective circle is to be inserted into a picture, the vanishing point of the plane upon which it lies must be used.

The lines of measurement will form the diagonals of the perspective square. A vertical line is drawn through the centre to the vanishing point, and another line through the centre at right angles to this. These lines meet the sides of the perspective rectangle at the points where the ellipse will be tangent to it. Draw vertical lines upward from the points where the circle intersects its diagonals, and connect the two points where these lines meet the scale line with the vanishing point. The intersections of these lines with the diagonals supply four more intermediate points, so that the ellipse may now be drawn with eight guide points. If the perspective rectangle is in

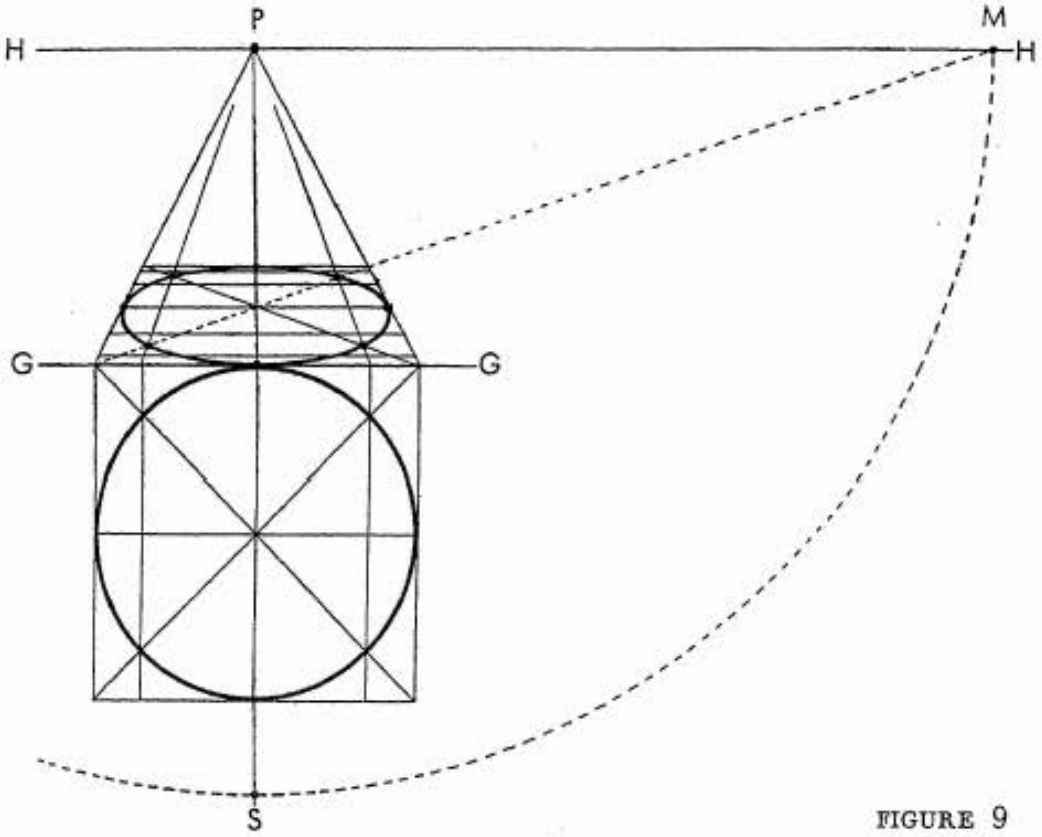


FIGURE 9

oblique perspective both points of measurement must be used and each of the two cross lines is drawn to a vanishing point instead of being at right angles to each other.

Notes on the Graphic Arts

The term graphic arts is in general use for designating all processes for the production of multiple-proof pictures on paper on a hand-made basis, the work being done either wholly or in most part by the original artist, and editions limited. The prints are ordinarily printed in black, occasionally in one colour, more rarely in multiple colours; and the individual copies or proofs are ordinarily numbered and signed by the artist, more often in pencil on the margin than on the plate itself. The term excludes all forms of

mechanically reproduced works photographed or redrawn on plates. However, some mechanical reproductions, especially the better ones of famous or popular paintings, are so well done and represent such a degree of technical skill that they are often valued as fine prints.

Japanese prints, for instance, have been condemned as works of art by certain connoisseurs and artists, especially by the Japanese, not only because they were originally works on popular subjects for distribution to the public, as distinguished from the more esoteric and precious paintings, but because their production was several steps removed from the work of the original artist and depended upon the co-operation of expert engravers and printers; they are now, however, as thoroughly accepted as the other forms of Japanese art.

The accepted graphic-arts processes are, in approximate order of their present-day popularity: lithography, etching, dry-point, wood cutting or wood engraving, aquatint, and soft-ground etching. Engraving on copper and steel, and mezzotint engraving are almost as obsolete in art as they are in commercial reproduction. They have their practitioners, but these are usually workers in other techniques who employ metal-plate engraving occasionally, rather than specialists who confine their major efforts to this medium. Although these processes were employed as art media in the past, their chief use was always in the multiple reproduction of paintings.

Copperplate etching has always enjoyed the position of an important if not a major art medium since the time of its mechanical perfection and improved control of effects, which date from the early seventeenth century. Early writers tell us that during the sixteenth century it was used in its first stages of development as a possible labour-saving substitute for engraving, attempts being made to subordinate its characteristic qualities in the interest of imitating engraved lines, rather than to exploit all its characteristics and evolve a unique tradition. The origin of etching has also been attributed to early metal workers and armourers who used it for decorative designs on metal.

The woodcut was the earliest form of multiple reproduction of pictures and designs, but it soon became obsolete for most purposes and was little used until its revival as an art medium in our own day. Wood engraving came into wide use as a means of reproduction and illustration during the middle of the nineteenth century, but newer reproduction methods introduced toward the beginning of the twentieth century caused it to become obsolete quite suddenly. Although the adaptability of its effects for certain work had caused it to be appreciated as an artistic medium to some extent during its life as a common means of reproduction, it was, with a few notable exceptions, never widely selected as an art medium until its twentieth-century revival as such. Woodcuts and wood engravings are often called block prints, to distinguish them from the metal-plate prints. The two groups are inked differently. The metal-plate processes, etching and line-engraving, are incised or intaglio processes; the ink is applied to the plate and wiped off, the lines being left charged with ink, which is deposited on the paper by running plate and paper through a roller press in contact with each other. The wood

blocks are inked by a roller which deposits a coating of ink on the raised surfaces; this in turn is deposited upon the paper by vertical pressure. Other characteristics which distinguish the effects of the various processes are: etched lines do not taper and expand as engraved or pen-drawn lines do, but are always the same width throughout; the grain of lithograph and aquatint masses and the fine lines of etching masses disclose more of the paper than the solid block print does, thereby imparting more granulation or depth to the print.

Limited Editions. The usual opinion is that proofs of the highest degree of excellence may be obtained only in limited editions, owing to sacrifices in finesse which must be made when a durable, lasting plate for quantity production is required.

A considerable group of present-day artists and commentators on art, however, point out that the graphic-arts processes were originally adopted not only for their sympathetic rendering of line, form, and tonal effects, but equally as much for the multiplication and consequent distribution of proofs. They claim that the limitation of editions by destruction of the plates or by the adoption of techniques and effects not capable of resisting for long the wear of continued impressions, is a comparatively recent development, and one fostered by artists and dealers for monetary reasons. They call the resulting rarity of such prints artificial, and cite the case of lithography, where the works of modern living artists command higher prices because of their scarcity than the proofs of some accepted masters of the nineteenth century whose works were turned out in fairly large editions. Although anxious to develop good craftsmanship, they are willing to sacrifice the attainment of superlative technical results if these require such delicate plates and time-consuming printing manipulations that large editions sold at low prices are out of the question.

On the other hand, the artist who, by great application and development along individual or personal lines, is capable of producing superlative proofs, continues to produce them in strictly limited editions. The term superlative proofs here implies prints which completely and thoroughly fulfil the most exacting requirements of perfection of control over the medium both in relation to the artist's intentions and from the viewpoint of the fullest textural qualities inherent in the medium itself.

This question, although it is not a purely technical one, must influence an artist in his choice of technique as it involves details and various adaptations of the graphic-arts processes. New standards of excellence, both artistic and technical, always become established with the development of any new methods and materials, and in their own way they become just as complete artistic expressions as the older traditional standards.

LITHOGRAPHY

Lithography was invented in Munich in 1798 by Aloys Senefelder, and thereafter came into wide use both as an artistic medium and as a means of reproducing pictures for publication.

Simply outlined, the process consists of drawing or painting with greasy crayons and inks on a particular species of limestone which has been ground down to the desired texture. After several subsequent manipulations, the stone is well moistened with water, whereupon the parts not covered by the crayon become wet, while the areas where the greasy drawing was made repel the water and remain dry. An oily ink is then applied with a roller; it adheres only to the drawing, being repelled by the wet parts of the stone. The print made by pressing paper against the inked drawing is not a reproduction in the same sense as is the mechanically reproduced print, but it is a true autographic replica, in reverse, of the original drawing on stone. The direct manner in which the drawing is made and the range of tones which can be obtained, make the process popular. Lithography is classified as a planographic or flat-surface process, as distinguished from the other graphic-arts processes, which are either intaglio or relief.

Lithography, unlike etching, enables the artist to confine his efforts to the execution of the drawing; because the printing is a somewhat mechanical procedure, the object of which is to turn out exact copies of the drawing as it appears on the stone, the great majority of artists have this work done by professional lithographers. However, it is generally considered necessary for the artist to have mastered the actual procedure involved in the printing process while learning lithography, in order to be thoroughly familiar with its requirements. Considerable knowledge and proficiency is required for the production of fine prints, and the number of professional artist-lithographers who can turn out really superior proofs from the stones entrusted to them is limited. This is particularly true in work which involves any great delicacy of tone or line. Some artists will carry their effort to secure completely faithful replicas of their original drawings to the point of having the prints made on paper of a tint that matches the original grey or tan colour of the stone.

The autographic quality of lithography is not always emphasized by some lithographers; for instance, Brown,[56] who based his instructions on the artist's carrying out every phase of the process himself, regarded the final proof as the principal consideration. In one case he worked on the introduction of a development whereby a new tonal effect was added during the printing process. Unless the printer is an accomplished expert, very sensitive or delicate tonal effects must be sacrificed.

Lithography is widely used as a means of commercial reproduction, and although the basic principles are unchanged, many variations in technique are used by industrial lithographic establishments. The artist has small concern with these procedures; none of them improve and most of them detract from the quality of the work from an artistic viewpoint, for the aims of the industrial lithographer are not those of the artist, and the commercial lithograph is definitely a reproduction, not an artist's proof. Practically every artists' lithographic process in use today was known, at least in principle, to the inventor and early workers of the craft.

Lithograph Stones. The limestone from Solnhoffen, Bavaria, with which Senefelder first perfected his original process, is the best. Many substitutes

are quarried in various parts of the world, but all are inferior. The best-quality stones are those of a grey or 'blue' colour. The yellow or tan stones appear to be of a softer or looser texture and not capable of taking such a satisfactory grain; also delicate work done on them is more likely to be injured during the printing process; nevertheless, some artists express a preference for them. Stones which show any colour variation are usually rejected, as streaks or spots indicate a variation in composition or texture which may interfere with the printing; but many such defects do not show in the final prints. A small stone, 10×12 inches, is about $2\frac{1}{2}$ inches thick and weighs about 30 pounds. For perfect proofs and to prevent breakage in certain types of presses, the thickness must be accurately uniform. The larger stones are made proportionately thicker; a stone measuring 18×22 inches will be approximately 3 inches thick and will weigh about 100 pounds.

The artist does not require many stones, as they are ordinarily cleaned and refinished as soon as an edition has been pulled, although the stone with its original drawing may be preserved for several years, if desired. The great majority of artists, especially those to whom lithography is a minor or occasional activity, own no stones but rent them from the printer or supply house, where they have the graining and resurfacing done. Few maintain their own presses, and a good proportion of the finishing and printing work they do is carried on outside their studios, in workshops of professional artist-lithographers, in art schools, artists' societies, and occasionally in an industrial lithographic shop. Much of the best work is done by artists under such conditions, with the close co-operation and supervision of professional printers, the best of whom are not only artists in their own right but sympathetic to and co-operative with the aims of the artist who makes use of their professional services. Although every material used throughout the technique is available ready-made in adequate quality, there are always a number of experimental-minded artists who make their own crayons and other materials, and who are constantly striving for improvements in the drawing and printing of their work.

Metal Plates. Plates made of zinc or aluminium, light in weight and just thick enough to be rigid, have long been in use to supplant the more cumbersome stones; in industrial lithography they have practically replaced them. They are sold ready-grained to imitate the texture of stone, and also in a variety of other grains for various types of artistic and reproduction purposes.

The technique of using metal plates is not basically very different from that applied to work on stone, but there are naturally many points of variation in manipulations. In the case of metal plates, the possible manipulations are more limited in number and are somewhat more difficult to master. Often, because of the darker tone of the zinc, the artist is led into the production of more contrast than he would create on the paler stone. An expert can ordinarily distinguish at once between proofs made from plates and those made from stones; those made from stones are universally considered to be superior, and although some artists find the plates adequate for some types of work, the stone retains its position as the standard material among artists.

Graining. The grain is imparted to the stone by grinding its surface with flint, sand, or other abrasives. The stones are finished by laying two of them face to face and grinding them with the abrasive and water. Metal plates are grained by machine; the grains of abrasive are tumbled upon their surfaces with small balls or marbles. Zinc plates do not act well when old; they should be freshly prepared, and protected against atmosphere and moisture until used.

Transfer Lithography. In order to overcome some of the limitations of lithography as compared with other methods of pictorial production, artists have for many years made lithographs in an indirect manner, by drawing with lithographic crayons on paper. These drawings, which are obviously made without many of the disadvantages and limitations attendant upon work done directly on the cumbersome stones or inflexible plates, are sent to the printer, who, by a rather simple process, transfers them to a stone or plate and turns out final proofs which are not reversed—that is, the picture is reversed when it is transferred to the stone, and the prints taken from the stone reverse it again so that they reproduce the original point for point.

In average hands, the resulting proofs are greatly inferior to those obtained by direct drawing on the stone or plate, and a person of any experience at all can detect the difference immediately. For simple sketches or simple black and white contrasts they often suffice, but for work of any degree of delicacy the process is not to be recommended to the average artist; in fact, it has been claimed that such prints should not be called lithographs. On the other hand, very fine results have been obtained with transfer papers, especially by the leading print-makers of the late nineteenth century, who were conscientious students of the process. By the use of specially coated transfer papers, work of considerable finesse and delicacy has been transferred to zinc plates with much success by experienced specialists.

Specially prepared and coated transfer papers can be purchased in two varieties: a thin tracing paper and a thick chalk paper. These papers have a grain which takes the crayon in a way that superficially resembles the effect produced by the average coarse-grained stone. The undesirable textures of the drawing in the final proof are caused partly by the fact that a reverse image or negative of the original textures of the crayon marks is deposited on the plate or stone in place of the textures caused by the stone itself in the direct method. Regardless of superficial resemblances in the textures produced, drawing with crayon on paper, as explained on page 17, is somewhat different, both in the mechanical action involved and in the results obtained, from drawing on stone or plate, the tooth of which is tiny pits rather than matted webs. The mechanical handling of the transfer will also contribute to loss in textural quality, although expert manipulation can keep such changes to a minimum.

The directions and precautions to be observed in making the drawing are practically the same as those for drawing on stone. The paper must be kept free from grease. Not so much freedom in manipulating the crayon is possible. The principal advantage of transfer over direct lithography is that an easily transportable pad or portfolio is available for rapid sketches.

Despite the superiorities of direct work on stone, large numbers of transfer prints are continually being produced. The results obtained by the use of coated papers approach the original lithographic quality more nearly than do those obtained with the common tracing papers.

Drawing on Stone. In most instances preliminary drawings or sketches the exact size of the print are made on paper and traced faintly on the stone as a guide to the drawing. The usual tracing material, to be rubbed or drawn on the back of the paper, is sanguine crayon which contains no grease, has no effect on the stone, and because of its red colour will not become confused with the black drawing. Some lithographers prefer soft lead-pencil lines. If too many chalk or lead-pencil lines are put on the stone, they may clog the grain and interfere with the action of the lithographic crayon.

The greatest care must be taken to keep the stone absolutely free from greasy impurities and adherent dust. Breathing upon the cool stone causes condensation of moisture, through which the crayon slides badly. One must never touch the sensitive surface with the fingers; in order to prevent smudging some convenient form of bridge may be used as a hand rest. A stave from a small barrel or keg is the simplest one.

The main point to be observed in regard to the drawing is to apply the crayon with the proper touch to obtain the desired effect. The normal lithograph texture is the granular one produced by more or less minute portions of the paper showing through the black printing ink, even in the heavy black areas. The crayon is dragged across the surface with a sensitive touch; if rubbed back and forth with a heavy hand, it would tend to fill up or overload the texture of the stone so that dull, coarse blacks would be produced instead of the luminous sparkle. The use of flat areas of tusche (mentioned below), or of benzol or other solvent, will create dead flat printing areas; such effects may of course be desired at times, but the normal technique avoids them. The use of a knife, a pointed rod of abrasive material, a hard ink eraser, and many improvised tools for scratching out or producing special results, is learned by practice and experiment; the extent to which one may employ very delicate effects depends upon the capabilities of the printer and is a matter of individual discovery. The variations in texture attainable by manipulation of the crayon are seemingly unlimited.

The Crayon. The two main requirements for a satisfactory crayon are: it should be of the proper degree of hardness to produce the desired mass or line effect on the surface and to work in a sympathetic manner; it should contain a correct blend of materials so as to deposit the necessary grease-receptive water-repellent printing areas. Crayons in the form of square sticks about 2 inches in length, as well as those in pencil form, are universally sold in an adequate range of hardness: No. 0, very soft; No. 1, soft; No. 2, medium; No. 3, hard; No. 4, very hard; No. 5, copal. Miller[61] recommends Nos. 3 and 4 for most uses, and the softer ones for use in cold weather only; he disapproves of No. 5 entirely. The crayons which are intended to be used in the customary crayon-holder or portcrayon and sharpened to suit exact requirements are sometimes considered more professional than the pencils,

which are perhaps easier and more convenient for the majority of artists; but this may be prejudice. Fine points are best made by sharpening with a thin blade from the point toward the holder rather than away from the holder in the manner of sharpening a lead pencil.

An inky liquid which contains the ingredients of the crayon in liquid form is much used for pen and brush work, and to produce solid blacks. This is called tusche,* never, correctly, lithographic ink; the latter name applies only to the printing ink employed to produce the final proofs, and its use in reference to tusche leads to confusion.

Lithographic crayons and tusche are always black, regardless of the colour in which the final proof is to be printed, because the drawing is judged and the printing manipulations regulated according to experience gained by working with black; a litho crayon made with a red pigment, for example, would distort all of the practitioner's judgment, based as it is on the black and white technique. Lampblack is used in crayons because it works well, is of the correct texture, and does not interfere with the functioning of the process.

Although the ready-made materials are of acceptable quality for normal practice, a few lithographers prefer to make their own, believing that they obtain superior results from special formulas. The following selected recipes are typical of the average materials in use:

Senefelder's Recipes	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Wax	4	8	4	8	8	8	8
Soap	6	4	4	4	5	5	6
Lampblack	2	2	2	2	3	3	3
Spermaceti			4	4			
Shellac					4	4	
Tallow						2	4

After being melted in a shallow pan in the order given, the blended materials are ignited and allowed to burn for a minute or so; then the flame is extinguished by covering the vessel. This procedure is repeated many times, and imparts hardness to the crayons. Upon cooling, the mass is cut or sawn into convenient pieces.

The lithographer who is interested in making his own crayons to meet various requirements will seldom be satisfied to copy old recipes, as commercial brands of crayons can be had to match the properties of most of these, but he will usually wish to do further experimenting. Brown[56] lists

* Not a customary term in Britain, the liquid is known here as lithographic drawing ink.

nearly a hundred formulas in his book and mentions some additional raw materials. The following are the properties which various raw materials will impart to the crayons. The chemical réactions of lithography are noted on page 326.

Ingredients which deposit strong printing areas:

Tallow—imparts softness and greasiness.
Stearic acid—imparts comparatively granular, non-sticky quality.
Oleic acid—softness, greasiness.
Palm oil—softness.

Ingredients which deposit less strong printing areas:

Beeswax—smoothness, adhesiveness.
Carnauba wax—hardness.
Japan wax—softness, some stickiness, adhesiveness.
Linseed oil—greasiness and softness.

Ingredients which have weak printing action:

Soap—smooth or slippery quality; also solubility in water. Necessary in liquid tusche. Liberates free fatty acids when wetted with water. Crayons will print but will not manipulate or draw well without it.
Mastic and other resins—stickiness, solidity.
Shellac—hardness.

Ingredients which have no printing action; small amounts will impart fluidity, softness, or smoothness:

Paraffin wax.
White mineral oil.
Vaseline.

The sole function of the lampblack is supposed to be to colour the crayons, but it also contributes a little solidity and drag to their drawing qualities. The addition of lye partially saponifies the oils and fats, but under the conditions of the mixture probably does not make complete soaps of them.

Preparation of the Stone for Printing. First the edges of the picture are neatly ruled off and the margins of the stone are thoroughly cleaned with snakestone and water. A rather wide margin, at least two inches all around, is necessary for convenience in printing. The manipulations as outlined in the following paragraphs are usually carried out in the order given, but sometimes the order is varied; occasionally some procedures are omitted and some repeated more than once, according to the preferences of the printer.

The Etch. At the beginning of this section the lithographic process was outlined, and reference was made to intermediate steps between the making of the drawing and the inking of the stone. The principal one is the application of the etch.

When the drawing has been completed, its entire surface is gone over with an acidified solution of gum arabic, which deposits a film on the uninked portions and completely desensitizes the stone, making it incapable of further grease adsorption. This solution is called the etch, a misnomer carried over

from the very earliest experiments by the inventor of lithography, who at first attempted to produce relief and intaglio printing surfaces on the stone. The etch does not eat away the stone with the crayon acting as a resist, to produce a raised or relief printing surface. More accurately, it could be called a fixative or desensitizer; any smudges or accidental inkings of the blank portions of the stone will not take after the etch has been applied; the ink will be confined to the drawing.

Both the gum-arabic film and the one deposited by the crayon are tenacious and insoluble, and may be repeatedly sponged and rinsed with water and turpentine respectively without injury to their water- or grease-repelling properties, or to the definition of their areas.

The stone at this stage is thoroughly desensitized, and the first part of our original outline explanation must be somewhat elaborated; the process actually depends upon the fact that the greasy crayon sets up an insoluble, grease-attracting, water-repelling condition, and that the acidified gum solution or etch sets up a water-attracting, grease-repelling condition, not by the action of superficial, adherent films, but in the surface of the stone itself. Further remarks on this subject will be found in the section on chemistry (page 326). After the etch has been applied and the subsequent manipulations have been carried out, the portions of the stone that have not been drawn upon are so desensitized that even when the stone is dry, if printing ink is smeared on these areas, it may easily be washed off with a damp sponge. When the stone has been thoroughly wetted, no trace of ink will be taken from the inking roller by even the most minute points of exposed stone. The further manipulations referred to, although they may be considered minor refinements from the point of view of the general underlying principles of the process, are actually of great importance in securing perfect results, and the manner in which they are carried out governs the success or failure of the printing process.

A typical formula for etch to be used on stone contains gum arabic and nitric acid. Dissolve gum arabic in the proportion of 1 ounce to 2 or 3 fluid ounces of water, and add C.P. nitric acid in small amounts until a few drops of the mixture applied to the face of a stone just barely shows a definite bubbling action—about a teaspoonful to 3 or 4 ounces of solution, or about 1½ parts to a hundred, will be required. Too much acid is suspected of being a cause of loss of delicate tones in the final proofs. The concentration of the gum solution is not a matter that requires accurate measurement. For zinc plates the most frequently recommended etch is chromic acid in the same amounts, with the addition of 15 or 20 drops of phosphoric acid; for aluminium, the chromic acid is omitted.

The etch is applied liberally all over the stone with a sponge or wide camel-hair brush, and dried by fanning; after it is throroughly dry, it is washed off with a sponge and water. The stone is then given an application of plain gum-arabic solution, and again fanned dry.

The crayon drawing is next washed off with turpentine, whereupon the image seems completely destroyed, but the grease-attracting, water-

repelling condition that was set up in the stone is still there. The stone is then rubbed with a small amount of a weak asphalt solution, fanned dry, washed with water, and inked while wet.

The inking roller is a carefully made piece of equipment on the order of a wooden rolling pin, smoothly and tightly covered with fine calfskin over a layer of felt. Loose leather grips over the handles allow for control in manipulation. The manner in which this implement is cared for and used throughout the process is of great importance.

The stone is now cleaned of all accidental defects; the margins are made clean, and, if desired, minor corrections are made on the drawing. The inked stone is then well dusted with powdered rosin (to make it more acid-resisting), and is re-etched for a few minutes and washed off, after which the rest of the process is repeated. When the stone is finally ready to be inked for printing, it is placed on the bed of the press, and while thoroughly wet is inked with the roller; the prints are made by placing dampened paper on the stone, protecting it with a clean sheet of paper over which a piece of fibre board is laid. Pressure is applied by means of a lever, and a crank runs the stone under a greased, leather-covered wooden scraper, which transfers the inked drawing to the paper.

The crayon drawing is washed out because it is composed of waxes, soaps, and other ingredients not desired in the final printing, which is done with an ink made with thickened linseed oil. If the crayon drawing were allowed to remain, it would eventually be carried away by the proofs and the inking roller, but the dozen or more prints made while traces of it were still on the stone would be wasted, as they would be defective in tonal qualities. The crayon is formulated solely for its drawing properties and the action it causes in the stone; it is not wanted after these properties have been utilized and the lithographic condition has been set up in the surface of the stone.

The first inking or rolling-up of the stone is an important step in completely establishing the permanent grease-receptive condition of the printing area.

Printing or Lithographic Inks. Black and coloured printing inks differ from the colours sold in tubes for oil painting in that they must be ground to the very finest sort of grain and the most complete dispersion possible, by being repeatedly put through powerful and accurately adjusted roller mills. The consistency requirements differ from those of oil colours in that printing inks must be capable of depositing on the paper a smooth, level, uniform stain rather than a thick painty layer. The colour effect is generally that of water colour, the underlying white paper contributing brilliancy and luminosity to the tones; but opaque colour effects are not entirely unknown.

In order to meet these requirements the ink makers produce a very stiff paste, capable of being spread or rolled out to a level flat film on the inking roller, and having just the necessary degree of snap or sticky tackiness, combined with a certain oiliness. Specially made litho varnishes, which are heat-bodied linseed oils, are cooked for the purpose, and are commonly burned or ignited during the process; their viscosities and other physical properties are

closely controlled, and the various grades are standardized and sold by universally known numbers. Litho varnishes which are combinations of two or more viscosities are often called for in ink formulas, not because any exact viscosity desired could not be produced, but because such mixtures will give results that are different from any that can be obtained by the use of a single oil (see page 312).

An ink-reducer or extender is a diluting medium with which a printing ink can be made weaker in colour or more transparent without its body or working properties being altered. Prepared mixtures are sold for the purpose.

Lampblack can be ground in litho varnishes in the same way oil colours are made at home, but the resulting material would be inferior to the manufactured inks, the production of which requires a high degree of skill and powerful machinery.

ETCHING

Etching consists of drawing with a fine steel point, or needle, on a soot-blackened metal plate which has been coated with a ground of acid-resisting wax or varnish. In the true etching, the drawing does not depend upon any lines the needle may scratch on the plate; the lines merely cut through the wax, exposing the brightly polished metal. The plate is subsequently immersed in an acid bath, which bites out or etches the exposed lines.

After the etched plate is cleaned, it is inked, and prints are pulled from it on a special roller press. Editions of thirty to a hundred proofs are commonly pulled, after which the plate is customarily destroyed. Technically, the size of the edition is limited by the ability of the metal to endure the pressure, which eventually wears down the sharpness of the lines. If the plate is steel-faced or electroplated, clear, clean editions of several hundred proofs may be produced. The question of the number of proofs to be made involves several considerations, as discussed on page 376.

The wax coating or resist protects the surface of the plate and confines the action of the mordant to the sharply incised lines; but after this action has proceeded a very minute distance below the surface, there is nothing to prevent it from eating away the metal horizontally as well as downward. The result is that the etched line is an undercut affair; the edges of the lines have little solidity or support and will wear away with greater rapidity than will those of an engraving, whose grooves have walls which are straight-sided or bevelled.

Each step in the etching process is very largely mechanical, subject only partially to individual control; but the handling of all the stages and the manner in which they are combined, make for entirely individual and sensitive results; judged by any standards, etching is a true fine-arts medium. If any of the steps are simplified or made easier by too radical departures from the traditional methods, the results will usually display some lack in the qualities expected of an etching. Because the lines made by the needle are uniform in width and do not taper or expand as do those of an engraving or a

pen drawing, because the action of acid is uniform on every part of the exposed metal, and because the pressure of the roller press should be mechanically uniform so that the proofs are alike, the artist must, as it were, play one mechanical step against another in order to exploit the medium to the fullest extent; he cannot control the sensitive quality of line, mass, or tone directly or completely in any single one of his operations. A technically perfect etching is distinguishable from a mediocre attempt at a glance; technique and artistic accomplishment are more closely interrelated in etching than in any other graphic medium.

The Plates. Smooth, highly polished plates of zinc or copper $\frac{1}{32}$ inch thick are commonly used. These plates are fairly easy to obtain at artists' supply stores; the specialist in etching, however, usually obtains them from one of the firms which specialize in etchers' or engravers' supplies. Copper is the traditional choice; it is preferred to the somewhat less expensive zinc on account of its superior crystalline texture or grain, its better behaviour throughout the process, and other qualities more subtle, which can be learned from an actual comparison of the two better than from a description.

Zinc plates, however, are adequate when the work is simple and without great delicacy of line or effect—especially when all the lines are of equal value or not too subtly different in value. Steel, a more coarsely grained metal, is sometimes etched; it is chosen for use only in the production of large editions, as in the case of commercial work or book-illustrations, and is incapable of application to fine prints. The earliest etchers employed iron or steel, and overcame its disadvantages to some extent by the exercise of much skilful effort, as well as by a realization of its limitations.

Copperplate etchings and engravings may be, and for large editions always are, faced or electroplated with steel; their resistance to the wear of continual impressions is thereby greatly increased, but some of the distinctive characteristics of copperplate etching may be lost.

Preparation of the Plate. Before applying the ground, the surface of the plate must be made perfectly clean by rubbing it with a soft cloth and one of the volatile solvents and a little whiting. If it is discoloured or tarnished, the application of a mixture of vinegar and salt will usually remove all traces of tarnish. The exposed metal must present a chemically pure surface for the mordant to act upon, and the uniform and complete adhesion of the ground requires a clean surface.

A special holder with a wooden handle and iron jaws is clamped to a corner of the plate, which is then heated and its face rubbed with a ball of wax ground, which is sometimes enclosed in a wrapping of cloth. Learning to apply the ground in a sufficiently uniform coating is a matter of experience; the thickness will depend largely on personal preference. Some grounds are intensely black in colour; others are transparent and require blackening so that the scratches of the needle will be visible. This is accomplished by holding the plate face down and smoking it for a few moments over the flame from a number of wax tapers twisted into a bunch. Some etchers dislike the sooty layer, and dispense with this smoking operation, especially when the

ground they employ is intensely black. I have tried blackening wax-gilsonite grounds by melting the wax and then dissolving in it some oil-soluble aniline black, such as nigrosine. This increases the ground's blackness and opacity.

The requirements for a perfect etching ground are: (1) it must give perfect protection to the plate against any concentration of acid which is likely to be used; (2) it must be of the correct degree of softness so that the needle will cut cleanly through it without any chipping, and expose the copper in clear, sharp lines; (3) it must not be so soft and tender that it will be easily destroyed by accidental handling or that the scraped particles will cling adhesively to the surface of the plate or needle instead of falling away as they should.

The traditional ground is pure beeswax or a mixture of beeswax and asphaltum. This can be and is improved upon by a number of special formulas; prepared grounds sold by dealers in etching supplies serve the purpose well and few etchers find it necessary to make their own. Among the published formulas which have been favourites of various etchers is the following, for Rembrandt's ground (so called), in parts by weight:

Yellow beeswax	2
Mastic resin	2
Asphaltum	1

Another version:

Yellow beeswax	4
Burgundy pitch	1
Common pitch	1
Asphaltum	4

Instructions: melt ingredients together carefully with occasional stirring, adding them in the order named. The molten material is inflammable; make small batches and guard against fire. Some recipes call for white beeswax.

These recipes probably originated in the seventeenth century. Paste grounds, which are applied with a roller, contain the same ingredients thinned down to the proper consistency with turpentine or mineral spirit.

The trouble with most formulas of this nature, especially the old ones, is that the asphaltum, pitch (rosin), and other materials are so unstandardized and vary so much in properties that one always has to do a good deal of adjusting and experimenting before the recipe begins to work as it should. The etcher who makes his own grounds, however, is usually a person who wants to experiment. The properties of the various ingredients are as follows:

Wax. The basic material for the ground; almost good enough alone, but needs the properties of the other ingredients to perfect it. Use as much as possible, which will probably be about half to one-third of the mixture.

Resin (mastic, damar, or rosin). The least acid-resisting of any of the ingredients. Use as sparingly as possible; its function is to set up or harden the ground, to make it less tender, and to raise its melting point.

Asphalts. Highly acid-resisting; the softer varieties will impart flexibility,

and the harder varieties will also contribute strength and resistance to handling. Asphalt will tend to shorten the mixture or lessen the natural sticky adhesiveness of the wax. The hardest and most brittle asphalt is gilsonite, which is like a hard resin; the softer, more elastic kinds among the standardized varieties are Trinidad, Barbados (Manjak), California, and Egyptian asphalts. There are a number of other soft asphalts, both native materials and by-products of oil refineries, which are used industrially in large amounts but which are sometimes difficult to obtain at retail. Asphalt will also colour the ground, but when the ground is spread thinly and evenly over a plate this colouring will be no more than a transparent brownish tinge, and for an intense black coating against which the copper-coloured lines incised in the ground will show up with greater contrast, the plate must be smoked.

Liquid Grounds. The prepared liquid grounds are made by dissolving the solid materials used in the regular grounds in a quick-drying volatile solvent. Ether and chloroform are the traditional solvents in use; the substitution of less dangerous materials from the long list of modern solvents available should be an improvement. The drawback to the use of liquid grounds is their tendency to collect dust particles, which produce weak spots in the coating. The liquid ground is applied by pouring it over the plate; the plate is manipulated so that the ground spreads evenly, then the excess ground is allowed to drain from one corner back into the bottle, an operation which requires some skill.

A recipe for a liquid ground which I have used in experiments is as follows: melt 4 ounces of beeswax; stir in ¼ ounce of powdered nigrosine base, or other oil-soluble aniline black, until dissolved. Pour into 2 ounces of gilsonite which has been melted in a separate can. Remove from stove and thin with a mixture of ½ ounce of kerosene and ½ ounce of mineral spirit poured in slowly with stirring, followed immediately by 8 fluid ounces of toluol. The petroleum solvent is used to start the thinning; if a highly volatile solvent were added first, it would cool the mass too quickly, causing it to solidify in lumps, and the solvent would boil away. (All thinning of varnishes must be done in places with good ventilation and in the complete absence of flames or electric heaters.) This ground can be made more brittle by adding rosin or mastic or by increasing the proportion of gilsonite, and softer by the substitution of a softer asphalt for the gilsonite. A liquid ground can also be made by thinning the molten wax with a ready-made solution of asphalt.

Etching the Plate. The plate prepared for etching is immersed in a bath of mordant, which bites or eats away the metal by chemical action. The commonest receptacle in use is a glass or china tray such as is employed by photographers; a wooden tank or one lined with sheets of lead could be used, if necessary. Acid-resisting porcelain-coated metal is not reliably resistant to the strong concentrations of acids employed in etching mordants.

The traditional mordant is 4 parts concentrated nitric acid and 6 parts water (concentrated C.P. nitric acid is a 68 to 70% solution of HNO_3). Nitrous acid, which is similar in action to nitric acid, is preferred by some

etchers. Further remarks concerning the action of acids in etching will be found under chemistry (pages 302 and 327). Before the acid is poured into the tray for use, it is customary to dip a strip of clean zinc into it for a few moments until it bubbles freely. This ionizes or begins the dissociation of the acid, and puts it in a condition which insures its immediate and steady, continuous action upon the plate. During the reaction between the acid and the copper, the bubbling which occurs should be watched, and if any bubbles start over areas which are supposed to be protected by the ground or resist, the plate must be removed at once, rinsed, dried, and given further protection by applying an acid-proof varnish or resist to these weak points. The defect caused by such accidental solution is known as false biting.

After the plate has been bitten to the correct depth to produce the finest or lightest lines desired in the particular work in hand, it is removed, rinsed, and dried, and the portions which are to remain finely etched are covered with acid-proof resist, applied with a small brush. The plate is then bitten again to produce the next coarser or heavier lines, and so on; experience will determine the depth to which the various kinds of lines should be etched. After the plate has been etched as far as one wishes to go, all traces of varnish or ground are removed with the appropriate solvents, and a trial print is made, whereupon the plate may be re-grounded and any corrections or additions made by further etching. There are several variations of etching procedure, and some etchers will change their techniques according to the particular work in hand.

Iron (ferric) chloride is sometimes used as an ingredient of mordants on the theory that its action tends to be more selectively vertical than that of nitric acid; that is, the lines will be bitten down rather than sideways (see page 385). This action is caused by the rapid deposition of salts on the little walls of the lines, their surfaces being thereby protected from further action of the acid. After a somewhat longer time, the bottom of the etched line also becomes clogged with these salts and the action ceases.

Before a plate is immersed in acid, the back and edges must be coated with a liquid resist or acid-proof paint. The usual material sold for the purpose is a solution of asphaltum in volatile solvent, which dries quickly to a rather brittle finish and which is sufficiently acid resisting to protect the plate from etching solutions. Ordinary shellac varnish into which a little lampblack has been stirred is also used for this purpose. If a wall of wax is built along the edges of the plate, acid can be poured upon the surface alone.

The ebullition caused by the action of nitric acid on a metal is rather violent (perhaps because a double reaction takes place) and tends to disturb the resist coating at its edges; the result is apt to be a coarsening of the lines. For this reason some etchers use the so-called Dutch mordant, a milder solution which appears to have originated about the middle of the nineteenth century; it is made by dissolving $\frac{1}{2}$ ounce of potassium chlorate in 5 fluid ounces of hot water, cooling, and adding $\frac{1}{2}$ ounce of concentrated hydrochloric acid. Dutch mordant has a milder action on copper than the nitric acid solution, and is considered more certain to etch fine lines sharply.

Potassium chlorate should not be used in other mixtures; it is not a safe substance for haphazard experiments. Correct laboratory technique calls for slow, cautious addition of any concentrated acid to water, never water to acid.

The remarks on materials used in an etching ground apply as well to the liquid resists or stopping-out varnishes, except that these varnishes do not have to meet such precise requirements and a larger variety of materials can be used, according to the judgment and experience of the user. It should be remembered that from the viewpoint of solubility, alcohol-soluble coatings, such as shellac, are different from those which dissolve in benzine, toluol, etc., such as the usual asphaltum and wax compounds; when a plate which bears both kinds is to be cleaned for printing, it must be washed with each of these types of solvent separately. The more powerful paint-remover solvents, such as acetone, will usually remove both kinds of coatings. Waxes and waxy materials are used to plasticize these acid-resisting varnishes, that is, to render them less brittle, so that when they are scratched through with the etching needle, the line will be clean and sharp. If, for example, the highly acid-resisting varnish made of pure gilsonite and solvent were scratched with a needle, the edges of the scratched varnish would chip away in a rough and erratic manner. An acid-proof stopping-out varnish or resist in the thin layers in which it is applied in etching, is usually just about adequately resistant to the mordant to accomplish its purpose, and cannot always be depended upon to resist stronger concentrations of acid or to withstand immersion in acid for extended periods of time.

An important consideration in etching, as in any other chemical reaction, is the temperature. In order to secure uniform, controlled results, and to be able to rely upon former experience in timing the etching periods, careful workers will use a thermometer. Normal room temperature, about 65° F., is standard; as is usual in most chemical reactions, heat accelerates and cold retards the action.

Soft-Ground Etching. Soft grounds are made of the same materials as the regular grounds, plus 50% of tallow. They need not contain any blackening material. When a plate coated with soft ground is covered with a sheet of paper and then drawn upon with a pencil, the ground under the pencil pressure will adhere to the sheet, and when the paper is lifted away, the ground under the lines of the drawing will come away with it. Such a plate differs from one made with a needle in that the line can be made to vary in strength through width instead of through depth of biting, and the plate may be bitten without so much use of stopping-out operations. The character of the line is more or less grainy, like that of a crayon line, depending upon the texture of the paper.

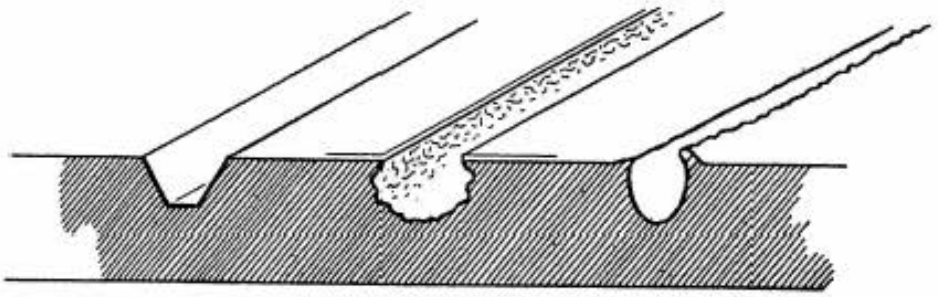
Dry Point. Technically, the dry point occupies a position between the etching and the engraving; the process is simple, direct, and autographic.

A copper plate, the same kind as is used for etching, is blackened with the soot of burning wax tapers, and the drawing is scratched directly upon its surface with a needle whose point must be sharp rather than rounded. Sometimes a diamond point is used. Gramophone needles are popular for use in

etching; they have rounded points. The plate is then cleaned, inked, and printed. Dry point and etching are often used in the same plate.

As illustrated in the drawing below, the natural dry-point line has a characteristic soft effect from the ink deposited by the burr or raised edge. This burr is delicate and will not hold up under any severe treatment or withstand the wearing pressure of very large editions; when required, it can be removed entirely by using a scraper, the same triangular-edged instrument used in copperplate engraving. A sharper line will then be produced. Dry point is considered best adapted for direct, spontaneous work, and its effects are less deep and varied than those of etching.

Aquatint. An aquatint is an etching in mass instead of in line, and is made possible by the application of a special ground which contains powdered rosin of various degrees of fineness. The acid surrounds these particles of rosin and bites through to the metal at their edges, thereby creating a grainy effect; the irregularities of the grains prevent the texture from appearing mechani-



Engraved *Etched* *Drypoint*

cal. There is no technical or artistic objection to combining line etching or dry point with aquatint; almost all aquatints require line work and rely upon it for many of their results. Such prints are usually called aquatints, even though the major part of the work is line. A great number of variations and modifications are in general use to produce a number of variously grained effects.

Aquatint is practised only by experienced etchers who have an inclination to experiment with materials and develop their own methods and manipulations; few artists are content to follow any set or standard procedures after becoming interested in the technique. The principal methods may be outlined as follows:

The plate is grounded by covering it with a layer of powdered rosin. This is accomplished by dusting the rosin on through a cloth bag, by sifting it through sieves from a height of several feet, or by shaking it around in a specially made box, then inserting the plate and allowing the powder to settle upon it. The plate is then warmed on an electric or gas heater for a few moments, which fuses the particles and causes them to form a hard ground of granular texture. If this were immersed in acid, the result would be a plate which would print a solid area of granular tone; the acid bites through the points unprotected or insufficiently protected by the fused particles of rosin,

which is a semi-acid-proof material whose resistance can be controlled by varying the thickness of film and the duration of etching.

Another method of graining a ground is to run a plate coated with regular etching ground through a press together with pieces of sandpaper, the operation being repeated as many times as necessary.

Before the biting, the picture is made by painting upon the grounded plate with regular stopping-out or resist varnish, and gradations of tone are produced by repeated biting and stopping-out.

Many varied textures are obtained by such manipulations as producing white lines by painting with resist varnish before applying the rosin, or by drawing on the plate with grease pencils which are acid-resisting.

Printing Etchings. In etching, the printing is so much a part of the complete process that the etcher usually prints his own plates. After he has succeeded in printing a perfect trial proof, he may turn the rest of the edition over to an expert printer, but the number of such experts is so limited and the effects are so dependent upon the artist's personal work, that this is seldom done. The planning of the composition, the original strokes of the drawing, and the biting of the lines are all carried out with the final printing in view.

The plate is inked by working the ink into the etched lines thoroughly with a dauber, in all directions. When the lines have been filled in with ink to the satisfaction of the printer, the surplus ink is wiped from the flat surface of the plate. Theoretically, a technically perfect etching should be wiped absolutely clean, and the final proof should consist of inked lines clearly printed on clean paper, without smudging or other effects caused by ink remaining on the flat areas of the plate. Actually, tradition and taste allow for considerable latitude in this connection, and the artist ordinarily obtains a number of different effects by manipulating the process of wiping the plate. However, over-dependence upon accidental inking effects is usually condemned.

The inks used in etching differ from ordinary printing inks according to obvious differences in function; they are, however, basically similar to the others in that they are black or coloured pigments ground into thickened linseed oil by roller mills. A number of satisfactory inks are on the market; the principal variation an etcher will need is in tone or colour. After a little experiment he will soon discover the make or type of ink that best suits his particular purposes, and will not usually change unless he changes the other details of his procedure. Etchings are ordinarily printed in normal, true black; sometimes they tend toward the brownish, or are even a definite brown. Etchings in other colours are rarely made. Multicoloured etchings made with single impressions by such procedures as inking various parts of a single plate by hand with inks of various colours, do not conform to artistic requirements and are not colour-etchings but coloured etchings. Colour-etchings would be made in the same way as other colour prints, by printing each colour plate separately.

Engraving on Copper and Steel

Successful engraving requires a well-developed personal skill in manipulating the gravers, or burins. The gravers are tempered steel instruments with oblique points and wooden or cork-covered handles which are designed to fit into the palm of the hand. The steel is grasped with the thumb and fingers near its point, and the edge of the thumb must press against and glide along the surface of the plate in order to guide the point in a free and sensitive manner and to prevent it from becoming buried in the metal. The plate rests upon a circular leather pad, and is held by the engraver's left hand in such a way that it can be tilted and revolved, these motions being coordinated with the movements of the graver and used equally, especially in engraving curved lines. When the work is finished, the burr which the graver raises in occasional and varied places must be removed by rubbing with a few strokes of the scraper held flat, after which the plate is ready for trial impressions. The scraper is a triangular blade with sharp edges, which removes the burr without injuring the plate. Printing is done as in the case of etchings, except that after the plates are inked they are wiped very clean; the printing of an engraving is an altogether mechanical operation.

Woodcuts and Wood Engravings

The term woodcut is correctly applied to work done by cutting out the surface of a smooth plank of hardwood with a knife, aided by the use of a few V and U gouges for more delicate lines. Seasoned planks of apple, pear, cherry, beech, and sycamore of type-high thickness (·918 inch) are used.

The term wood engraving is applied to work done on blocks made by sawing the wood so that the surface is the end of the grain; and instead of knives and gouges, gravers are used—the same tools which are employed in metal-plate engraving. Carefully prepared blocks of boxwood are sold for this purpose, as well as pear blocks, which are considered second choice but are adequate for most uses. Compared with woodcutting, wood engraving is essentially a white-line-on-black-background technique; that is, one works from black to white to a greater extent than when cutting on a plank where larger areas of white are incised and the black and white masses are manipulated more equally. The earliest masters of the woodcut produced work of strength combined with delicacy of line, but the technique is at present considered more adaptable to robust, free work, while the wood-engraving technique is preferred for work which requires more refinement or accuracy of line. The modern print maker will more often than not combine both techniques on a single block.

At the peak of its development during the nineteenth century, wood engraving was used principally as a means of reproducing drawings and photographs, and its characteristic qualities were subordinated to the production of imitative effects. Its use as a purely artistic technique is modern.

Minor Graphic Processes

Under this heading may be grouped several techniques which for various reasons seldom attain the dignity of seriously developed art media. Their limitations or qualities may be more suited to light or decorative work than to significant or 'monumental' art, their processes may not be amenable to precise control, or their effects may be lacking in appeal to discriminating taste—usually for sound reasons.

Linoleum Cuts

The limitations and restrictions imposed upon an artistic medium by certain intractable materials are overcome by a competent mastery of the technique; exploitation of all the medium's desirable qualities then becomes possible. As a result of this, a certain element enters into the work which enhances it, according to most artistic doctrines. In such traditional techniques, the substitution of newer materials which lack some of the properties of the old materials, and which do not present such difficulties, will result in effects which lack this element; it is for this reason that the easily cut linoleum is less esteemed by artists than is wood. The linoleum will not take very delicate or subtle cutting, and its characteristic effect is composed of rather blocky or poster-like forms. However, the technique enjoys a certain popularity among artists for the production of less important and more casual work.

For the most part, the remarks on woodcutting apply to linoleum cutting; lighter-weight tools made for the purpose are now sold in place of the regulation wood-carving knives and gouges, but they are less satisfactory. Linoleum is composed of burlap coated with a heavy layer of linoxyn, which is made of polymerized oil mixed with ground cork and pigments. The best grade is known as battleship linoleum, and is usually brown or grey. If desired, it may be mounted or purchased ready-mounted on wooden blocks so that the cut is type-high in order that it may be taken by a printing press. Small, inexpensive presses may be purchased or improvised; when regular printing ink is used the printing presents few difficulties. Fairly satisfactory (but not perfect) impressions may be made even by such makeshift procedures as placing the inked linoleum cut and the paper between boards or between the leaves of magazines, and bearing down on them heavily with one foot.

The Monotype

The monotype occupies a place between the graphic arts and painting, the proofs being unique and not precisely accurate multiple reproductions. Because these proofs are indirectly produced and printed on paper, and because usually an artist turns out an edition of several copies or versions of the same subject, monotypes are generally classed among the graphic arts. They usually display accidental effects; ordinarily no effort is made to pre-

vent this, and only approximate results are expected in the making of duplicates.

The usual monotype is a painting in any convenient medium which does not dry too rapidly—ordinary oil paint, printing inks, or even aqueous paint—done on a metal plate or a sheet of plate glass, either freely or following a transferred outline drawing. A sheet of paper is laid over the painting, held firmly with the fingers of one hand so that there is no lateral movement, and rubbed with any convenient implement to effect the transfer of the painting. Many variations suggest themselves to artists, and there are few standard methods.

Silk-Screen Printing (Serigraphy)

I have placed this process among the minor techniques, not for any of the reasons noted above, but because it is of such recent development that no widespread use by large numbers of artists and no standardization of materials have been possible as yet. The method is simple in principle and execution; it is basically a stencil process, where the designs are placed upon a piece of fine-mesh silk tacked to a wooden frame, various film-forming materials being used as resists. The specially made colour in the correct semi-liquid consistency is poured into the frame, the frame is placed in contact with the surface to be printed upon, and the colour is scraped over the stencil with a rubber squeegee, thus being deposited upon the paper or other ground through the meshes of the uncoated areas of the silk. The wooden frame upon which the silk is stretched is made about two inches deep so that it forms a box (with the silk constituting the bottom) within which the paint can be conveniently manipulated with the squeegee. Although successful monochrome prints can be made with one impression, almost all of the development work on silk-screen printing as a fine-arts medium has been done with the aim of producing colour prints in a full, unlimited range.

In the past, artists have taken up many stencil processes for the multiple production of their works, but because of technical limitations none of these have developed beyond the status of minor techniques or mechanical reproductive processes. The silk-screen techniques, however, present all the major attributes of a true graphic-art medium, and if their development proceeds in the future as it has up to the present, they should soon attain a permanent place among the accepted graphic-art media. The name serigraph has been proposed as a designation for an artist-made silk-screen print in order to distinguish it from silk-screen work that has been executed on an industrial or purely reproductive basis. The prints may be described as resembling gouache paintings, with some colour-lithograph qualities, specific effects varying according to the technique or style of the artist.

The origin of the silk-screen process has been explained in various ways, but its development as an art medium stems directly from the advances and standardizations made in its industrial use during the past two decades. An early adaptation of the process was the decoration of textiles in loose, free-

hand patterns, the resist portion of the stencil being painted with an opaque oil paint or lacquer, and starch- or gum-thickened solutions of water dyes being used. With the introduction of Profilm,* a patented material which replaced the liquid resist, the process became more adaptable to use by individuals and decorating departments of various establishments, as well as by workshops which specialized in silk-screen printing for various purposes.

Today these activities have assumed the proportions of an important industry served by a number of dealers in supplies and equipment. Profilm consists of a thin film of coloured cellulosic or synthetic material of the type that is readily dissolved by the various lacquer solvents, mounted on a sheet of glassine paper with rubber cement, the whole transparent enough so that drawings can be traced through it. Stencils are cut from this material with a small, very keen stencil knife, care being taken to cut through the film but not through the paper. The cut-out areas are removed, and the finished stencil is made to adhere to the frame-stretched silk by placing it face down upon it and applying lacquer solvent to the back of the silk, whereupon the film will partially dissolve; when it has dried it will adhere. The paper backing is then peeled off. After the margins around the stencil have been coated with a lacquer resist and the edges protected on both sides with gummed tape or similar material in order to make a tight seal between the silk and the frame, the stencil is ready to print. The tape as well as the wooden frame should be shellacked.

This process is applicable to work of some delicacy, such as fine lettering, simple designs, posters, etc., and may be used alone for some types of artistic work, but for the completely controlled intricate printing areas demanded by free artistic drawing, modifications must be employed. The film process may be used as a basis for or in combination with other methods if desired.

Silk-screen printing was first publicly sponsored as a fine-arts medium by the New York WPA Art Project, which organized a producing unit for silk-screen prints as a division of its graphic-arts department. The development of the process for artists' use is due largely to the work of Anthony Velonis, who has made considerable progress in establishing and standardizing techniques and in furthering their adoption by artists. The following outline is based largely upon his practice and recommendations.

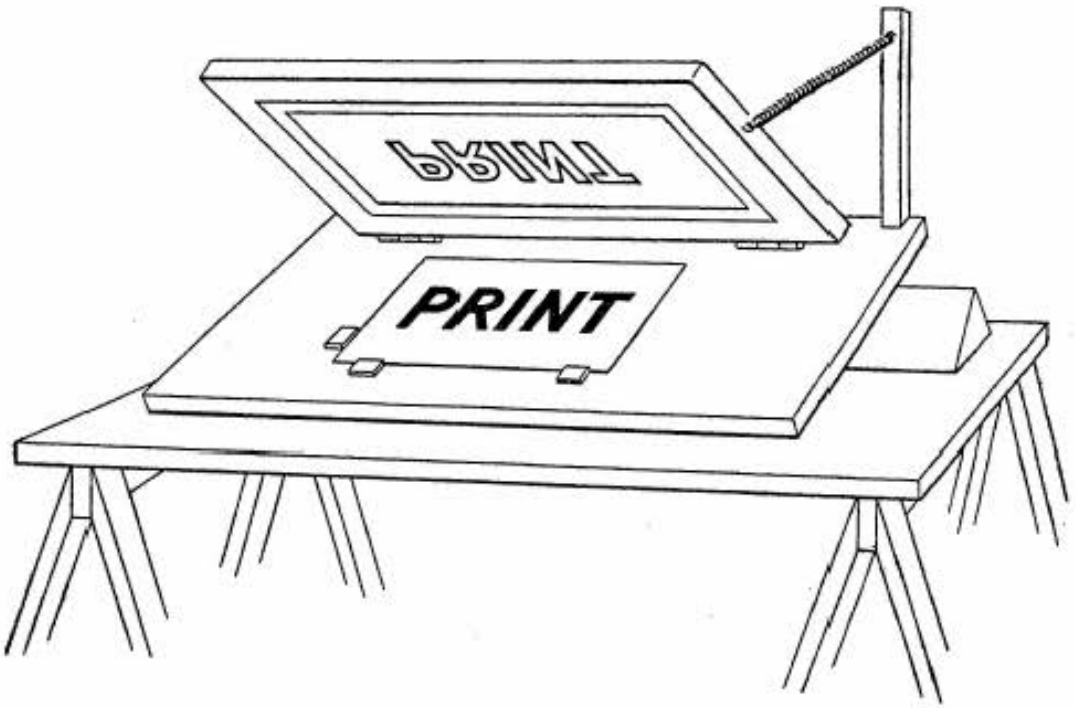
The frames are sturdily built of good timber about 2×2 inches, and brass hinges with removable pins are fastened to one of the long edges (referred to here as the back edge) so that the frames can be hinged to the 'table' (a plywood board somewhat larger than the screen) and interchanged. The silk used is sold for the purpose in two weaves, bolting cloth and taffeta or stencil weave, in many degrees of mesh, from 00 (coarsest) to 18. Numbers 12 and 14 are average. The silk is tightly stretched by tacking it on the frame or by using a special clamp frame, after which the margins and edges are treated as previously described. The frame must be large enough so that a margin can be left around the drawing for manipulation of the paint.

Printing operations are facilitated if a screen-door spring is attached to an

* Selectasine Silk Screens Ltd., 11 Southampton Row, W.C.1.

upright at the back edge of the table, and hooked to the side of the frame near the front edge so that the frame is held up some inches above the table and is in contact with the paper only while the print is being made. Registers similar to those used when paper is placed in a printing press, are made by gluing three small squares of thick cardboard or celluloid to the table as guides for holding the paper in place, two along the front edge and one at the left near the front.

Before the printing operations are started, the 'table' is propped up at an angle on the actual table or horses upon which it is used, by placing a length of wood under its rear edge.



Tusche-Washout Method. Fasten the original drawing or painting to the table with drawing pins or Scotch tape in such a manner that after it is removed it can be replaced again in the identical spot. Let the prepared and taped screen down over it and with a pencil trace outlines or guide points of the colour area to be printed.

Paint the picture directly upon the right side or top of the silk with lithographic tusche (see page 381), using various brushes and manipulations, according to the effect desired. Allow to dry. Prop the screen at the corners so that it is level, right side up, and coat entire silk, including the drawing, with glue applied evenly and neatly with a squeegee. A good mixture is Lepage's liquid glue 50, water 40, vinegar 6, glycerin 2. When this is dry, repeat the glue coating and allow to dry again. Turn the screen over, and impregnate the tusche areas with mineral spirit or kerosene. Place the screen on newspapers, right side up, and apply more of the solvent liberally, spreading and rubbing gently with a neatly folded rag. Remove the top sheet of newspaper, add more solvent, and continue rubbing until the tusche is washed out. The

glue over the tusche will flake away; use a nail brush to remove obstinate spots if any remain. When the printing areas are entirely clean and clear, the design will be surrounded by a glue resist, the silk is ready for printing, and the frame is replaced in the table hinges.

A wide variation in textural results can be achieved by drawing on the screen with a No. 2 lithograph crayon. Sketch in the printing areas with a lead pencil as described above, then place the screen over any desired textured material such as sandpaper, a file, engravers' Ben Day plate, Ross board, egg-shell board, etc., and work with the crayon over the areas to be printed. Apply the glue resist and wash out the crayon as in the regular tusche method. Crayons may be used either alone or in combination with tusche or other methods.

Simple Cut-In Method. Instead of producing the printing area by direct or positive working, one may outline it in a negative technique, that is, by painting the silk around the drawing with glue or lacquer and leaving the printing area open. This method is rather difficult to apply to designs of any great finesse, but it is very useful for free, loose work and can be used to produce a good deal of variety.

Glue-Shellac Method. Squeegee the glue solution over the entire screen; when it is dry, touch up any pinholes with a brush. If there are many, a second very thin coat of glue may be used. The screen will be transparent enough for the drawing to be traced through it. Using a brush and black shellac or black lacquer, cut in the areas which are not to be printed. This can be done much more effectively here than in the preceding method because of the good surface created by the glue.

Touch up errors, pinholes, or thin spots with additional shellac or lacquer. When the screen is dry, prop up off the table in a perfectly level position, right side up, and wash the glue out of the printing area by going over it very carefully with a clean soft rag dipped in water. Wring out the rag, pick up excess water, and repeat; the glue dissolves only gradually. Do not flood the screen with too much water. Continue applications until the printing area is clear, then wipe with a dry cloth. Work only on the top side of the screen. This kind of stencil prints fairly sharp outlines and holds up well for long runs, but is not often used by artists.

Other Methods. A number of less effective methods are in use; they are applicable principally to simple or crude designs. A reverse process, that is, one using a water-insoluble resist and aqueous paint, might have desirable properties, except that a water paint has a tendency to cause the silk fibres to warp or expand and thus throw the work out of register somewhat. The most developed aqueous paint method employs Profilm, applied by ironing. Another one is a reverse of the method described with tusche, in which the printing area is painted with a water-soluble paint or glue, and when this is dry the entire screen is coated with imitation shellac (real shellac being too difficult to remove from silk screens). The glue or paint is then washed out of the screen with water from both sides, and the finished stencil is dried and printed with an aqueous paint. Despite much effort, a perfect water paint

has not been developed; the most successful have been made of starch paste, honey, glycerin, and preservative. Metal screens may be had in very fine meshes and are not affected by aqueous mediums, but they do not work out well in practice; they are expensive, and the slight accidental contacts involved in normal handling, which do no harm to a silk screen because of its elasticity, will ruin a metal screen by causing permanent dents.

Multicolour Prints. The methods for producing multicolour prints are in general the same as those used in any graphic colour-printing process, except that the serigraph has the advantage that a key screen which will print the complete design is in the great majority of pictures unnecessary or undesirable. The number of colours and textural effects which may be employed is unlimited, and colour applications may be continued indefinitely, the same as in a painting. Transparent and opaque areas may be manipulated in many ways, and there is no appreciable expense attached to the use of a dozen or more separate screen impressions if desired. The paint is carefully rinsed out of the screen at the end of each run; the same stencil may be reprinted in another colour or partly blocked out and reprinted in part; when the resist is no longer required, it is carefully removed by washing it with the appropriate solvent, and the screen is ready to receive another drawing. Two silk screens will be sufficient for the average artist's use. Depending upon the size of the editions and the number of colour impressions used, the silk will eventually wear out and require replacement.

Equipment. All the equipment and materials for the process may be purchased from the regular dealers in silk-screen supplies* and from some artists' supply stores, at prices which are very low in comparison with the cost of the usual graphic-printing equipment; the mechanical items can be made by simple carpentry if necessary.

The material sold as transparent base is a vaseline-like paste of alumina hydrate ground in the same vehicle as the pigments with which it is intended to be mixed to produce transparent effects. Its use is an important factor in the production of good prints. It may be mixed with regular artists' oil colours, if desired. The mediums are formulated to work well in the process and to dry very rapidly—needing from a half-hour to overnight.

Further Improvements. The paints used at present are industrial products and are not formulated to conform to artists' criteria of permanance. Although it has been pointed out that they are of the same quality as printing inks, it must be remembered that printing inks are applied in thin layers which act as mere stains on special papers, while serigraphy deposits a real paint film. The paint-film character, whether in thin glazes or opaque layers,

* Though there is considerable activity in commercial silk-screen printing in Britain, not enough artists have interested themselves in the process to encourage a single retail dealer in silk-screen supplies or to encourage the Artist's Colourman to stock specialised materials. The organdie is in short supply and preference is given not only to known trade customers but to orders for larger quantities than the private artist would normally require. It is suggested that artists interested in the process approach one of the several silk-screen printers listed in the Trade Directory, who may put him in touch with an amenable source of supply or consent themselves to furnish him with the small quantities he would require.

is one of the outstanding qualities of the finished prints and contributes largely to their optical and artistic success. In this connection, it must be remembered that any paint layer is subject to a number of eventual defects if not carefully formulated. Simple tests would indicate whether or not the pigments and mediums used in the industrial products meet artists' requirements as to permanence. The composition of the mediums used in the present commercial paints is unknown; the colours bear fantastic designations, and the earth pigments are missing from the lists. There is no reason why mediums and colours cannot be formulated to meet artists' requirements.

Some Notes on Sculptors' Materials

These notes were assembled for the purpose of beginning a study of the properties of various materials used by sculptors, the literature of which is scant.

Modelling Materials

Modelling Wax. The simplest modelling material is a prepared non-hardening plastic substance universally sold for the purpose. The traditional high-quality material, which originated in Italy, is a mixture of tallow, sulphur, and a special type of clay. It lasts indefinitely and can be used over and over again, so long as it is kept clean. It has just the proper mechanical or plastic properties, and is customarily of a green-grey colour. Modelling waxes are sold under a number of trade-marked names, such as Plasticine, etc. The cheaper grades are imitations of the original material; they generally hold their shape well and are adequate for most purposes, but are always inferior to the best or professional grade. Their composition varies; they are usually made of clay, other inert filler, and colouring matter, combined with various petroleum or paraffin greases and oils.

Clay. Clay is a native earth consisting largely of kaolin combined with silica. Many varieties of clay occur in nature, and various small percentages of impurities are the chief causes of their distinctive properties; for every use there is a best-suited variety. When wet, all clays are plastic to some degree and can be modelled; if the moulded objects are fired in a kiln or furnace at high temperatures they become hard and rock-like, retaining their shapes. Some of the most plastic modelling clays, however, are not well suited to ceramic uses. The varying degree of plasticity in clays has been attributed to a number of chemical or physical causes, and the question is still greatly disputed.

Sculptors' clay is selected for plasticity and moisture-holding properties at a sacrifice of other properties which are important in potters' clay. Sculptors' clay is used only to make models which are to be cast in some other material soon after they are completed. Useful varieties occur in all parts of the world.

Sculptors' clay will last indefinitely in its original powder state or if kept in a wet or moist condition; when it is much kneaded and aged in the moist

state it improves in plasticity. If wet clay is allowed to set and harden, a considerable amount of reworking, usually by mechanical means, is required to bring it back to its smooth plastic form; on account of its low cost and the labour involved in reworking it, hardened plastic clay is ordinarily discarded. When a piece of sculpture is being moulded in clay, it must not be allowed to dry out, because of the cracking and shrinkage which would ensue; it must therefore be moistened by a liberal spraying or whisking of water every twelve to twenty-four hours, and in the average climate is best wrapped in damp cloths and then covered up to minimize evaporation of moisture during periods when the work is set aside. This is most easily accomplished by constructing a light, movable framework covered with oilcloth with the coated side in. Wet clay is stored in a pail or tub, it is covered with wet cloths, and the container is closed with a tight-fitting lid.

Terra cotta is a ceramic clay usually but not always containing iron oxide, which imparts a characteristic reddish colour to it. Pale, whitish varieties are also in use, as well as those of intermediate colours which are obtained by mixing clays and by adding small amounts of iron oxide or other colouring ingredients; but the traditional terra-cotta colour is a pale tile red, such as would result from mixing burnt sienna, white, and a little red oxide. Sculpture modelled or cast in this material is directly fired in kilns and made permanent and durable. Its surface may sometimes be coloured, glazed, or enamelled with various ceramic materials before firing.

Plaster of Paris is described on page 324.

Stones

The use of a fine snow-white or creamy-white native marble of smooth crystalline structure by the ancient Greeks established this material as a traditional standard for artistic sculpture and architecture in Europe. The Romans perpetuated this tradition by using similar white marbles; they also carved many other native stones. In England and America the standard marble, and for many years in the past the only acceptable standard sculptors' medium, has been the pure white or slightly toned Carrara marble from Italy. Sculptors, however, have always employed an almost unlimited number of stones of various colours, textures, and degrees of hardness, durability, and ease of manipulation. Each one is selected not only for its technical fitness for the work in hand but also for its appropriateness to the nature of the work.

All stones are perfectly durable and permanent when preserved under normal indoor conditions, but for outdoor use they vary greatly. The conditions which outdoor sculpture have to withstand are both chemical and mechanical, and include wearing or abrasion and destruction by water, frost, and the action of acid or acid-forming gases in the atmosphere. Few stones will withstand great heat, as in the case of fires. I do not know of any researches into the durability of artistic stone sculpture under exposure to weathering, but from the studies which have been made of different kinds of

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building stone subjected to the severe conditions of industrial centres, it is clear that great care is necessary in the selection of stones for outdoor sculpture. The remarks on page 229 regarding the durability of outdoor frescoes and the effects of normal and polluted atmospheres apply also to artistic sculpture.

Marble and Limestone. Chemically and geologically, limestone and marble are closely related. Both are usually composed of more or less pure calcium carbonate; some marbles are dolomites—calcium-magnesium carbonates containing approximately two parts of magnesite to three of calcite. Commercially, the term marble is used in a broad sense, and is applied to many of the finer varieties of limestone, particularly those which are close-grained and will take a polish or will display decorative patterns or colour effects when polished. For sculptural purposes, marble may be defined as a smooth, close-grained, compactly crystalline calcium carbonate, capable of taking a smooth, high polish; it is usually white, although coloured marbles in great variety are also used. Limestone in this connection is softer, more easily worked, and commonly of a characteristic light grey or tan colour, with a smooth, close-grained, but rather dull and sandy instead of crystalline texture, which takes a mat surface rather than a high polish. A glossy polish on marble is never durable under outdoor conditions. Oölitic limestones are composed of small, rounded grains bound together compactly.

Because marble consists of practically pure calcium or magnesium carbonates, it is extremely sensitive to the solvent action of air polluted by acids —principally carbonic acid from the carbon dioxide normally present in the atmosphere, and the sulphur acids which originate from smoke and soot, both formed by the action of moisture. Marble is not an indefinitely permanent stone when exposed to the elements or to the atmosphere of industrial centres, as can be seen by the wearing away of old gravestones and monuments, especially those which have been subjected to the high concentration of atmospheric impurities in cities. There is considerable difference in the resistance of various marbles to atmospheric action, however, and the dense varieties selected for sculptors' use are among the most durable. The occurrence of flaws or defects in the interior of a block of marble is a matter that cannot be foreseen, but in general these defects occur with less frequency among the selected grades than among the others. The better grades of Italian statuary marbles are particularly free from major flaws, but sometimes contain 'pinholes'. Only the most compact and hard marbles and limestones should be used in outdoor sculpture.

Oölitic limestones occur in England in great variety, the strata extending from Portland Bill through Somerset, Gloucester, Oxfordshire across the Midlands to Northampton and Lincolnshire. The west country oölites are known as Bath Stones. Colour varies from almost white (Beer and Burford), through yellow (Doulting) to a deep yellow brown (Ham Hill) in the soft and medium limestones of which consistencies the following stones are representative: SOFT—Beer, Box Ground, Burford, Campden, Coombe Down, Corsham, Doulting, Guiting, Monks Park and Nailsworth; MEDIUM—

Ancaster, Clipsham, Ham Hill and Portland. The last named is the most generally useful and adaptable of all English stones.

The harder oölites—Grey and Blue Forest of Dean; Grey and Blue Lias; Grey, Blue and Brown York; and Hopton Wood partake of the nature of marble. All are difficult to work, the Lias stones and Hopton Wood, a pale brown in colour and the most beautiful of the English marbles, may be polished.

Most oölites, particularly the Cotswold stones, carve more freely when they are freshly quarried.

The most desirable grade of Carrara marble is known in the trade as Italian Statuary, a snow-white or creamy-white stone of fine, compact, crystalline grain; it is the standard for working qualities and finish. The grade called Blanco (Bianco) P. is a bluish-white variety of the same general properties.

Among the many limestones, the French varieties enjoy the best reputation among artists; they are mostly cream-coloured stones with excellent sculptural properties. Some of the principal names are Caen stone, Peuron, Lotharinga, Euville, and Normandeaux. Soft, porous limestones may weigh as little as 110 pounds per cubic foot, and the compact varieties 150 to 170 pounds. Limestones vary in colour from white to black; most of those in general use, as stated above, are pale tan or grey.

Sandstone is a porous material composed of fine particles of silica; different varieties have their grains cemented together by calcium carbonate, clay, iron oxide, or silica binders. The last-named material is the most durable. The English sandstones occur in the Midlands—in Warwickshire and Staffordshire. The principal varieties are—Brown and Blue Hornton, Red Midland, Robin Hood, Runcorn, Mansfield, Ketton and Hollington (gritstone) of which Robin Hood is the hardest and most difficult to carve, Hornton the easiest, but in all cases the abrasive action of the silica blunts the tools. Their colour, with the exception of Blue Hornton which is a bluish grey, lies within the brown-pink (Robin Hood), yellow-pink (Ketton) range, the Red Midland sandstone having the precise hue of milky cocoa. Some sandstones disintegrate quite rapidly when used outdoors, while others are among the most permanent of stones. Freshly quarried sandstone often contains natural moisture (quarry water) which dries out after cutting; such stones become harder, less porous, and less easy to carve.

Brownstone is a sandstone which contains iron.

Onyx marble is a translucent variety of marble which when polished acquires a glass-like quality and exhibits layers and figurings of a variety of colours. It is seldom used for artistic sculpture. Usually it is available only in small pieces.

Alabaster is a pure, snow-white, translucent or semi-translucent stone; two entirely different minerals of similar appearance have been used under this name. The material which has been in common use for many years is a variety of gypsum (calcium sulphate) which occurs in large solid masses. It is very soft, can be scratched with the finger nail, and is durable only under

conditions of careful conservation. It can be blocked out with a hand saw. Inferior pieces sometimes contain brownish veins and clouds. The other kind, which was used by the ancients, is pure white calcite, a native calcium carbonate of definite crystalline structure, really a type of marble.

Granite is a much more compact, durable mass than marble; it is carved with greater difficulty, and for outdoor use is a stone of far greater durability and permanence of polish than marble. It occurs in many variations of composition, colour, texture, and hardness. The most durable kinds are well known for their use in building construction and are generally of a greyish or reddish colour. They consist largely of silica and silicates. Geologically, or from the viewpoint of their origin, granites are in a different class from the other stones mentioned here; they are cut from igneous rocks, formed by the cooling of molten material; the other stones are classed as sedimentary rocks, deposited by water from the decomposition of other matter.

Soapstone is a silicate of this same class; it is rather soft and easily worked, but will resist great heat and severe chemical conditions. Because soapstone is so easily worked it was used by primitive races for making implements, cooking utensils, and sculpture.

AVERAGE WEIGHTS OF VARIOUS MATERIALS IN POUNDS PER CUBIC FOOT*

Alabaster (carbonate)	170
Alabaster (sulphate)	143
Brick	120
Cement (solid)	196
Clay, dry	120–160
Cork	15
Glass	150–175
Granite	170
Limestone (average in general use)	160
Metals	
Aluminium	170
Bronze	520
Iron, cast	449
Iron, wrought	480
Lead	708
Marble, average	162
Mortar, lime	103
Plaster of Paris	140
Sandstone (average)	155
Soapstone	170
Terra cotta	121

* Compiled from several sources. See page 416 for woods.

CEMENTS

Cast Stone and Cast Concrete. Models in clay, plaster, or modelling wax may be sent out to be cast in artificial stone, a material which can be made to duplicate exactly almost any natural stone in colour or texture, and the best varieties of which are at least as durable as the stones generally used for carving. The process requires expert workmanship, and although there are many establishments that can produce cast stone of a quality adequate for average architectural use, there are few craftsmen who can turn out satisfactory casts of sculptors' work of the proper degree of durability and strength. The material can be refinished, carved, and polished after casting. The usual composition of commercial cast stone is similar to that of a high-grade Portland cement and sand mixture, but the individual workers on artistic cast stone will seldom give out any information regarding details of their process. A magnesia cement, as described below, is probably used more often than Portland cement. Aside from the durable and varied results, the chief advantage of these methods over the duplication of models by commercial stone carvers is the saving in expense. Instead of using casting methods to duplicate the effects of carved stone, sculptors are beginning to employ it in an entirely separate technique in which its own properties can be used to achieve new effects, especially in colour.

Portland cement, so called from its resemblance to an English building stone, is an artificially compounded mixture of lime, silica, and alumina, made by calcining limestone and clay in kilns or furnaces. Some varieties are made from a natural mixture of these materials which occurs in certain localities. All brands of cement vary in properties in accordance with the locations of the factories, cement being made in places where all the materials can be quarried locally. Native and artificial cements were used in ancient Rome, where the latter were made from slaked lime mixed with a fine volcanic ash, notably that obtained from Pozzuoli. Such materials are still in use to a limited extent today; they are called Puzzolan cements. A white variety of Portland cement is also on the market; this is somewhat inferior in strength and other mechanical properties but is widely used for its colour effects. Cement is sold in 94-pound bags and must be kept dry; preferably it should be fresh stock.

Neat cement, or pure cement and water, is not used for structural purposes very often. *Cement mortar* is composed of cement and sand mixed with water, usually in the proportion of three parts (by volume) of sand to one of cement. *Concrete* is a mixture of three ingredients—cement, sand, and coarser pieces of crushed stone or similar inert material. The coarse pieces are called the *aggregate*. The addition of about 2% of plaster of Paris to cement mortar or concrete delays its setting; the substitution of hydrated lime up to 10% of the volume of cement makes the mortar more plastic without changing its properties appreciably, except that a slight additional denseness or water-resistance may result. The sand and also the coarser pieces, or aggregate, perform the same function as the sand in lime mortar described under

Fresco Painting, but the hardening and setting of concrete is a more complex and less well-understood process than the hardening of lime mortar. The assorted sizes of the sand grains and aggregate have much to do with the strength and compactness or porosity of the resulting mixture. After the initial set, which starts as soon as the water begins to evaporate, cast concrete must remain in its mould or forms for at least a day and, after it is removed, the rapid-setting variety will require about a week to attain its full strength; the slow-setting variety will need a much longer period. Cement is hydraulic, that is, it will harden or set under water, and after casts are removed from their moulds they are often immersed in water or covered with wet cloths for the purpose of curing them while they are setting.

Cement and concrete mixtures may be coloured by the addition of pigments up to 10% of their volume. The following pigments are in use:

Black—Black oxide of iron, artificial or native.

Blue—Ultramarine or cobalt blue.

Red—Pure artificial red oxides or Mars colours.

Brown—Umbers and siennas.

Yellow—Mars yellow, ochre, raw sienna.

Green—Chromium oxide and viridian.

White—White cement is used, with minimum additions of titanium or zinc oxides if necessary. Marble dust is also employed.

The addition of some pigments to cement has a definite effect upon the strength of the mass. Lead-bearing pigments, pigments which are water-soluble, and those which react with or are harmed by the alkali in cement, could not be employed, for obvious reasons. Copper and lead pigments weaken the mass considerably, as do zinc white, some of the carbon blacks, and some impure red oxides, especially Venetian red. The umbers and the pure red oxides or Mars colours will strengthen the mass somewhat, and the best grades of ultramarine have a very definite strengthening effect upon it. The others have little or no effect. These remarks are based on the results of architectural use and laboratory testing. Sometimes the brilliant aniline toners and other semi-permanent pigments are used in the colouring of cement for industrial purposes.

In casting cement the materials are measured and mixed dry as thoroughly and intimately as possible; water is then stirred into the mixture until the mass is just wet enough to be handled properly in the use for which it is intended. Moulds are filled by pouring the material in and tamping or packing it well. Too much water will cause separation and floating of fine particles to the surface. As in similar procedures, the best cement work requires an experienced hand. The usual mixes are, by volume:

For general all-round purposes: *Mortar*—1 part cement to 3 parts sand. This mix is used more often than any other. *Concrete*—1 part cement, 2 parts sand, and 3 or 4 parts aggregate. *Lean mixture for walls, etc.*—1 part cement, 3 parts sand, 6 parts aggregate.

Cement sculpture in the round is cast by the usual sculptors' methods. Modelling can also be done in cement, solid or over an armature; such work

may be made hollow in order to decrease its weight by covering the framework with wire netting, and plastering this with a mixture of 3 parts of Portland cement to 1 of aged lime putty. Rough modelling can then be done with a mixture of 2 parts of cement to 1 of finely crushed aggregate; and the finish coat, which should be kept thin, may be made of 5 parts of Portland cement to 1 of lime putty, pigments being added if desired.

As previously remarked, these notes deal primarily with materials; references to applications and methods of procedure are incidental and are not to be taken as a manual of instruction.

Although our present-day Portland cement and concrete are considered modern developments from the point of view of their widespread manufacture and use and the improvements in their properties, they are really materials of considerable antiquity. The Romans used the earlier Puzzolan cements for many of the same purposes for which we use concrete, and they were well aware of the various mixes of cement, sand, and aggregate best suited for various construction purposes.

Plastic Magnesia or Oxychloride Cement. This product is perhaps best known for its use in the building trades in making composition floors, stucco for frame houses, etc. The nomenclature of the basic material used is somewhat vague, and the dealer from whom it is purchased should understand the purpose for which it is wanted; it is variously called plastic magnesia, calcined magnesite, caustic magnesite, and light-burned magnesite. It is made by calcining magnesite, a native magnesium carbonate, at a limited temperature so that it is not entirely converted to magnesia (as limestone is converted to lime) and a little less than 10% of the final product is still magnesium carbonate. The rest is magnesium oxide plus whatever impurities happened to be in the original ore. Dead-burned magnesite, roasted until all the carbon dioxide has been driven off, is unsuitable. The main sources of supply of the magnesite used in Britain are Greece, India, Yugoslavia and Austria. Which of these sources provides the best material for sculptors depends upon the following factors: setting time, difference in volume before and after setting, final hardness and colour. It is considered that material of Greek, Indian and Yugoslavian origin, of which the colour is white, sets faster than the Austrian, of which the colour is cream. The final hardness of all of these materials shows no marked difference after twenty-eight days.

When this product is mixed to a plastic consistency with a *strong* solution of magnesium chloride, it sets rapidly to a hard mass; and when used like Portland cement, that is, to bind together a mass of inert material, it is known as oxychloride or Sorel cement. The solution of magnesium chloride must be tested with a hydrometer (page 426), which should read from 18° to 25° Baumé (1·14 to 1·21 specific gravity). A quicker-setting mix and a stronger mass can be made by using a slightly more concentrated solution, 22° Baumé (1·18 sp. gr.), while some workers prefer a still stronger solution, 24 to 25° Baumé (1·20–1·21 sp. gr.). The material can be used by sculptors to model sketches, for which purpose it is a time- and labour-saver compared with the procedure of making plaster casts. Some workers have been very successful

in using it in the making of cast or artificial stone, achieving various colour and textural effects by adding cement colours, marble chips, and other substances. In moulding or casting any kind of cement, best results require expert manipulations, gained by experience. The addition of inert materials gives various structural properties to oxychloride cements.

At least two sizes of aggregate must be used, one coarse, such as sand or marble grit, the other fine, such as silica, clay, magnesia, etc., so that a compact mass will be formed, the voids between the coarse sand being filled by the finer grains.

Since the discovery of this cement by Sorel in France in 1853, no complete version of its chemical composition has been worked out, and technical advances, tests, and formulations have been made in an empirical manner. Upon setting, the cement forms a mass of interlocking crystals of mixed magnesium oxychlorides; a colloidal or physical action also takes place, similar to that which occurs in the setting of lime, a gel being formed which ultimately binds the aggregate into a rock-like, cohesive mass. Because the mass expands instead of shrinking, the setting reaction apparently occurs before the water has a chance to evaporate.

The following weight recipes have been recommended by the Dow Chemical Company* as examples of typical or starting-point formulas.

Standard Testing and Stucco Mix

1 part plastic magnesia	(12·5%)
2 parts 120 mesh silica	(25%)
5 parts Ottawa sand	(62·5%)

Ottawa sand† is a standardized material used in tests of various kinds; it consists of uniform, rounded grains of pure silica sand.

Standard Flooring Mix

5 parts plastic magnesia	(50%)
3 parts silica	(30%)
2 parts shredded asbestos fibre	(20%)

Bureau of Standards Flooring Mix

45 parts calcined magnesite
15 parts silica
15 parts wood fibre, medium
10 parts talc
10 parts asbestos
5 parts red iron oxide

* Seaton, Max Y., 'Plastic Magnesite and Oxychloride Cement.' *Chemical and Metallurgical Engineering*, Vol. 25, p. 233. New York, 1921.

† The standard sand used for cement testing in Britain is specified by the British Standards Institution as coming from Leighton Buzzard, Bedfordshire, where it can be obtained from George Garside, Esq., or from his agents.

Sculpture Cast in Metals

Bronze. The traditional metals for casting works of art from clay or wax models are bronze, which is normally an alloy of copper and tin, and brass, which is normally an alloy of copper and zinc. Alloys are used instead of single metals because of their more desirable properties; the various metals impart certain characteristics to the mixtures. The compounding or formulation of an alloy is not a haphazard matter, but is an involved and complicated study, and the various formulas approved for specific purposes have been adopted for good reasons. There are innumerable recipes for bronzes, most of which are designed for specific purposes other than the casting of works of art. Modern sculptural bronze usually contains an addition of zinc, melted in just before casting. Small amounts of lead and other metals are also found in various bronzes.

The use of more modern innovations such as aluminium, stainless steel, and Monel metal, is so recent compared with the traditional use of bronze, that no standards have been established, and sculpture in such materials may still be classed as experimental. Foundries are more likely to use a regular standard alloy than to mix special formulas for sculpture. The principal concern of the sculptor in the selection of bronze is probably colour.

Metal casting is ordinarily done in foundries by craftsmen experienced in the careful handling of sculptors' models; only a small minority of sculptors have sufficient first-hand experience or knowledge to even criticize or guide the work in progress, although a general understanding of the processes should be acquired in order to plan models from which technically successful castings can be made, and so that the results will coincide with the original intention.

It is not the aim of this brief survey of sculptors' materials to go into any detailed account of methods and procedures, but some mention must be made of them in relation to the properties of materials.

The two standard methods for casting bronze from clay or plaster models are the sand-casting method and the *cire perdue* or lost wax method. The sand process is the one in common industrial use; the lost wax process is the traditional method for hollow casting of sculpture. Either one may be used for artistic work, depending upon circumstances. The method in use for the reproduction of a piece of sculpture by the lost wax process consists in making a negative gelatin piece-mould of the original model and from this mould making a hollow model in wax, by coating the inside of the assembled mould with molten wax. After the wax model has been assembled, packed with foundry sand, and corrected and reworked by the sculptor, rods of wax are attached to it in several places. The model is then encased in fire-resisting plaster or clay; the entire structure is held together by means of pins, and placed in a hot oven or kiln until the clay mould becomes dry and the wax has melted and run away through the vents or holes in the mould caused by the wax rods, which had been arranged so that they ran through the clay. The mould is then packed into sand, well supported by a sort of built-up kiln, and

melted bronze is poured in through the apertures or gates which were provided for by the wax rods. After the bronze has cooled, the mould is removed, the sand core is shaken out, and the casting is cleaned and finished.

In the sand method, a mould is made from a special foundry sand packed around the model; this mould is enclosed in a steel frame (flask), the two halves of which fit together accurately and closely. A sand core is then fitted into the mould so as to leave a space between it and the mould, into which the melted bronze is poured. All metal castings require chasing and other finishing operations after they are taken from the moulds.

The casting of hollow bronze statuary is an ancient procedure, and the early bronzes of all civilizations have been well studied and analysed. Details may be found in the works of Lucas, [26] Partington,[27] and other writers on various early cultures. Both of the methods outlined above have been traced back to early times, and it is doubtful which one antedated the other.

Melting Points of Some Metals in Degrees Fahrenheit. These figures have been compiled from a number of sources. Further data on bronzes will be found in Henley[80] under 'Alloys'.

Aluminium	1216	Iron	2741
Antimony	1166	Lead	621
Arsenic	1562	Nickel	2646
Cadmium	610	Platinum	3191
Chromium	3488	Silver	1760
Copper	1981	Tin	450
Gold	1945	Zinc	787

Colouring and Toning of Sculpture

Plaster casts are coloured with paint coatings, more often to imitate some conventional sculptors' material than to produce highly coloured effects or to use colour as a part of the design. The patining or toning of bronzes is usually done by chemical treatment.

Colouring Plaster Casts. Before paint coatings are applied to absorbent, porous materials such as plaster, the surface should be sealed or sized in the same manner in which linen canvas or plaster walls are sized before oil painting, in order that the coating may take evenly and adhere permanently. Very thin solutions of glue or casein can be used, but the best size is shellac diluted to a very thin, fluid consistency with alcohol. The shellac must not be strong enough to give a glossy finish, as this effect is likely to persist and impart a glossiness to the final coating; also it will prevent the final coating from adhering well. Thin coatings of size should be applied until the surface begins to show a faint, incipient gloss; then they should be allowed to dry thoroughly.

For the green patine, or *vert antique* finish, which simulates corroded bronze or copper, the first coat is an oil or casein paint of a dark brown colour, about the shade of an old penny. When this is dry, a bluish-green paint is stippled on with the end of a bristle brush; this paint should preferably be made of copper carbonate, a pigment which is chemically the same as the

actual corrosion on copper and its alloys. The green may be tinted or toned with other pigments to obtain variations in shade, and when dry may be coated with flat varnish; or the pigment may be mixed with flat varnish or with white flat wall paint. However, casein binders are most popular for painting plaster casts, and realistic stone effects are obtained by tinting a casein paint with various pigments and coarse inerts. More uniform textures may be produced by spraying than by brushing. Stipple coats should be of very thick consistency—a semipaste is about right—so that the stipple effect will not flow out and entirely conceal the undercoat. A final finish or protective coating for sculpture, either painted plaster or bronze, is a wax paste rubbed in well with cloths. A wax salve can be made by melting white beeswax and thinning it with a solvent.

Patine on Bronze. The natural finish on bronze is usually preferred; bronzes will age to various dark brownish tones, depending upon their composition. The green, blue, or red patine found on ancient bronzes can be rather easily reproduced by chemical treatments which result in coatings of approximately the same chemical composition as that of the patines produced during the natural corrosion of copper and its alloys. Bronze is an alloy of copper and tin, brass of copper and zinc, but much statuary bronze contains additions of zinc and other metals in various amounts. The green copper carbonate patine is said to be more permanent than the blue variety; the latter, when artificially produced, is likely to revert to the green form upon ageing.

The general formula books[89ff] give many recipes for colouring metals by immersing them in or coating them with chemical baths; probably the most reliable calls for washes of dilute acetic acid alternated with exposure to the fumes of strong ammonia. Nearly all the published recipes for greens call for chlorides, but according to Fink and Eldridge,[98] the use of sal ammoniac, hydrochloric acid, or any other chloride is to be condemned because chlorides will induce 'bronze disease', a malignant form of corrosion which spreads rapidly and has a destructive effect upon bronze. The same authors recommend that the antiquing of valuable bronzes be done as much as possible with fumes instead of with solutions, and they suggest wetting the object and placing it in a closed box or cabinet with a dish of the volatile material on the floor. Their intention is to produce a permanent, stable coating which will not cause progressive decay. By first exposing the bronze to the fumes of strong acetic acid or ammonia, or both, and then to carbon dioxide from a cylinder, they obtain coatings of blotchy greens and blues which have a natural effect. An imitation of the red patine is produced by submerging the bronze object in water in which precipitated chalk is suspended, and which contains 2 to 3% of iodine (tincture of iodine having been added); the object is kept in this solution from 3 to 8 days. After all patining operations the bronze is thoroughly dried, preferably in an oven, and waxed with a paste of beeswax in toluol.

In applying the ordinary published formulas for patines it will be found that manipulations are as important as exact formulas for securing desirable

results. The following formulas were taken from a number of sources and are typical of a great many others; recipes for producing nearly any colour on metals can be found in the above-mentioned books.

Vert Antique. Produce a dark brown or blackish finish on the bronze by heating with a torch and, while it is hot, applying a solution of 1 or 2 ounces of potassium sulphide (liver of sulphur) and 2 or 3 ounces of lye in a gallon of water. Over this, stipple the following solution with a paint brush:

Copper nitrate	8 ounces
Ammonium chloride	4 ounces
Acetic acid	4 fluid ounces
Chromic acid	1 fluid ounce
Water	1 gallon

When this is dry, brush on another coat if necessary.

Verde green

Copper nitrate	5 ounces
Ammonium chloride	5 ounces
Chlorinated lime	5 ounces
Water	1 gallon

Use at ordinary temperature.

Bluish green

Sodium thiosulphate	1 ounce
Iron (ferric) nitrate	8 ounces
Water	1 gallon

Apply boiling or nearly boiling.

Red

Copper sulphate	6¼ ounces
Basic copper acetate	1 ounce
Alum	2½ ounces
Water	1 gallon
A few drops of acetic acid.	

Use hot.

Woods

The blocks, logs, and planks of wood used by sculptors must be well selected from properly seasoned stock, and as free as possible from defects in the inner mass of the wood. Obviously, many such defects are discovered only as the outer portions are cut away, and in some woods they are impossible to foresee; certain species of wood are notably free from such flaws, while others are more likely to exhibit them. If the wood has a very pronounced, bold grain or is distinctly two-toned in colour, these markings will have their effect upon the sculptural forms, and while experience may be a guide to the sculptor in planning his general results, most of such graining will contribute entirely accidental markings. In the veneer industry, where thin plies of

wood are sliced or sawn from the log at various angles in order to take full advantage of various grainings and markings, the manufacturer is seldom sure of the exact results until the log has been cut.

Both hardwoods and softwoods are used by sculptors; the requirements for a satisfactory wood are that it should last indefinitely and not be subject to splitting, cracking, or similar defects during work or upon ageing. For general purposes a wood which presents a pleasing and responsive texture under the tools is preferred, but some of the close-grained hardwoods are also used; these are difficult to cut and chip away. A most desirable property in any wood is uniformity or freedom from irregular soft or hard spots. The woods technically best suited to carving are uniform and solid throughout. The logs of some woods have cores (heartwood) much less dense than the outer wood and of an entirely different texture.

Artistic wood sculpture may be stained or dyed any colour, and oiled, waxed, or polished like furniture, but this procedure is seldom, if ever, resorted to; rather, the material is ordinarily left as nearly in its original state as possible. Some woods may be given a high smooth polish by simple rubbing; others, notably walnut, have a naturally attractive finish after being cut. When a smooth yet natural finish is desired, most hardwoods will take on a pleasing surface if rubbed or buffed with thin shavings of their own wood.

The following descriptions of various woods apply to dried and cured products obtained from dealers. The use of blocks or logs obtained directly from domestic or forest trees is not recommended unless one is experienced enough to be able to cure and season each variety in the correct manner, and to know what to expect in the way of internal defects and subsequent splitting, warping, etc. Non-artistic uses of some woods are mentioned as indications of their properties and as guides to their appearance.

American Walnut. This is the standard wood for carving; its texture, grain, uniformity, durability, and surface quality leave little to be desired. It is obtainable in logs 12 inches or more in diameter and in blocks cut to any desired size. The colour, while it varies a little and may sometimes be streaky, is never far from the well-known dark or medium brown. There is some variety of graining; it runs from a straight grain to a rather curly effect.

Fruit Woods. Apple and pear wood and, to a lesser extent, plum wood are used. These are rather soft, but otherwise perfect materials for carving. Their colours range from a golden yellow to a yellowish red; their grain and texture are smooth and uniform, and they have great permanence and stability. Apple wood is normally obtainable in small blocks and in logs which run from 6 to 10 inches in diameter and about 3 feet in length. Pear may usually be bought only in timber form, in planks 1 to $2\frac{3}{4}$ inches thick, 6 to 12 inches wide, and 6 to 8 feet long. Plum wood is less common. Fruit woods are not normally met with in the timber merchant's yard but it is possible to obtain supplies of Apple, Pear and Plum in most country areas; Cherry wood can most frequently be obtained from these home-grown merchants.

Cherry Wood. This material resembles mahogany in its reddish colour,

and has a pronounced straight, uniform grain. It is obtainable in logs 12 inches or more in diameter and in planks 1 to 4 inches thick, 6 to 12 inches wide, and 8 feet or more in length.

Mahogany. The strength, durability, and closeness of grain of this red wood are well known. Some experience and skill are required to carve it, because many specimens will display splintery or softwood qualities. The best and hardest varieties come from Mexico, Cuba, and Santo Domingo. African and Philippine mahoganies are valued for their interesting grain in veneer work, but they are rather soft woods, less desirable for carving. Mahogany is to be had in large sizes, the logs running up to 48 inches in diameter. Blocks cut to any size are usually available.

Lignum Vitae. This is the heaviest, hardest, and densest commercial wood. It is difficult to work, but is valued by a few sculptors for the rugged, stone-like effects which may be produced. The grain is uniform and fine, the surface takes a high natural polish, and the colour varies from a light olive green to dark brown or nearly black. The wood is obtainable in logs which run from 3 to 24 inches in diameter and from 2 to 10 feet in length. It grows in the West Indies and in Nicaragua.

Maple and Birch. These are hardwoods of very similar character; both are to be had in several grains. The texture is hard; the colour varies with different kinds, but is generally uniform throughout. Most varieties are rather too plain and uninteresting in grain to be popular for use in sculpture. Both woods are available in logs and blocks of various sizes.

Ebony, African. This is a perfectly black, dense wood of close smooth grain, rather tough and difficult to work. The choicest grade is called Gaboon ebony, logs of which usually vary from 4 to 8 inches in diameter and from 3 to 4 feet in length. Rather small blocks are usually available.

Other Woods

The commercial demand for rare and fancy woods for furniture veneers has made a large number of woods (mostly of tropical origin) available on the market. Other imported woods are used for various mechanical and decorative purposes. Most of the materials in the following list have been selected as suitable for carving when special or unusual textural or colour effects are desired; a few more common domestic varieties have also been included. Drawbacks to the use of some of the woods listed are their high cost, the fact that they are rare or not widely employed, the supply being therefore irregular, and the difficulty of obtaining them in large enough blocks.

The remarks on dimensions and availability are subject to continual revision, because trade conditions vary from time to time, especially with some of the rarer woods. These woods are imported into Britain in varying quantities, largely in the form of logs, sometimes, as in the case of Balsa, Basswood and Canary, in plank form. They can usually be obtained through a timber merchant but only against the production of a licence to acquire and consume issued by the Board of Trade Timber Control.

Avodire. An African hardwood of light colour and fine, silky texture, used in large quantities for decorative work. Available in planks 1 and 2 inches thick.

Ayous. A similar African wood, somewhat softer than avodire, with a pronounced striped grain. Comes in large logs.

Balsa. A well-known softwood of cellular structure and extraordinary light weight, used for a number of mechanical purposes. Obtainable in blocks and planks.

Basswood. A common American and Canadian softwood, easily worked. Has an even texture and a straight grain. Available in planks.

Boxwood. Two varieties are on the market; the West Indian is more common but less esteemed than the Turkish. Boxwood is tough, hard, extremely fine-textured, of a pale creamy colour, and rather difficult to work. Used for wood-block engraving. Comes in round and half-round logs 6 to 8 inches in diameter, and also in rather small blocks cut to dimension.

Camphor Wood. A hardwood from Formosa, with a strong camphor odour. Available in planks 4 inches thick.

Canary (Brazilian Satinwood). A light yellow wood with dark streaks. It has a hard texture. Available in 1- and 2-inch planks.

Cocobola. A very hard, dense, tough wood of a bright red colour and variable grain, imported from Nicaragua and Panama. Familiar through its use in knife handles. Comes in logs 6 to 8 inches in diameter, and in planks $\frac{5}{8}$ to 2 inches thick, 4 to 6 inches wide.

Degame (Lemonwood). A Cuban hardwood, yellowish to creamy white in colour. Comes in logs 10 inches or more in diameter and 12 to 14 feet long.

Ebony, Brown (Partridge, Coffeewood, South American Grenadilla). Comes in logs 12 inches or more in diameter and 6 feet or more in length.

Ebony, Macassar (Coromandel). From the Dutch East Indies. Comes in logs 12 inches or more in diameter, and 8 feet or more in length; also in planks. Both this and brown ebony find the same uses as African ebony, but are considered inferior substitutes.

Harewood (English Sycamore). A variety of maple with a fine, delicately figured grain. Comes in several colours—pink, silver grey, and weathered—all of which are obtained by dyeing.

Imbuya (Embuya). Sometimes called Brazilian walnut on account of its brown colour. Has a figured grain; comes in logs of various sizes suitable for carving and in planks 1 to 2 inches thick.

Koa. A very light-weight Hawaiian wood, hard, durable, and with a pleasing grain.

Koko (East Indian Walnut). A hard, dense, close-grained dark brown wood from Burma. Available in logs and in planks from 1 to 2 inches thick.

Lancewood. A rare wood similar to degame, but considered its superior in strength and resiliency.

East Indian Laurel. A dark, reddish-brown wood with a wavy grain, strong and elastic. Comes in large logs up to 30 inches in diameter and 10 to 17 feet long.

Rosewood, Brazilian (*Jacaranda, Palisander*). Valued as one of the finest of the rare woods. The rosewoods are all smooth, even textured, and easily finished. They come in huge logs, in planks, and in blocks of almost any desired size.

Rosewood, East Indian. Striped grain; colour varies from a straw-yellow to red or deep purple.

Rosewood, Honduras. The lightest-coloured rosewood.

Satinwood, East Indian. Long valued as one of the finest decorative woods. Has an excellent lustre, a golden colour, and a varied, figured grain. Comes in big logs and in planks.

Satinwood, San Domingan. Considered the best variety of satinwood. Used by the early designers and makers of fine furniture. Obtainable in planks.

Teakwood. Several varieties of teak known as Java, Rangoon, Malabar, etc., are obtainable in a variety of colours, but mostly golden brown. Sometimes teakwood has a wavy or streaky grain. Besides being adaptable for many mechanical uses because of its great strength, durability, and resistance to severe conditions, it is also well suited for solid carving. Available in logs, in blocks cut to dimension, and in planks.

Density of Woods

No table of the densities of woods can be precisely accurate, because of the number of variable factors involved. The following table has been compiled from several reliable sources and checked with actual dealers' supplies. Blocks of wood for carving are sometimes sold by the pound.

Weight of Various Woods

In pounds per cubic foot, in normal air-dried condition. Fresh or green wood will vary appreciably.

Aspen	25	Mahogany, African	34
Balsa	7·5	Mahogany, West Indian	24
Basswood	25	Maple	35
Beech	41	Oak	42
Birch	42	Pear	47
Boxwood, Turkish	63	Plum	51
Boxwood, West Indian	53	Pine (average)	35
Cherry	40	Redwood	27
Chestnut	39	Rosewood, Brazilian	50
Cocobola	75	Rosewood, Honduras	71
Ebony, Indian	72	Satinwood	64
Ebony, East African	62	Teakwood	40
Lignum Vitae	84	Walnut	37

The Use of Formulas

In using formulas, a certain understanding of the subject is necessary; while in general they are to be accurately followed, especially where they are accompanied by minute instructions, they sometimes serve best as hints or starting points for independent development of recipes to meet one's own needs and requirements. This is more true of the older or outmoded formulas; the modern ones are usually in accordance with the average requirements of the times.

Very old recipes must be interpreted with care. Our nomenclature, the quality of various present-day grades, and the modern understanding of basic principles underlying technical practices are often at variance with those of former times. Many untried and often-copied recipes have been reprinted in various recipe books; some of these are or have become unworkable, while some have been taken from the specifications of patents which are sometimes incomplete or not entirely practical.

Often procedures which originally had some foundation in reason have been blindly perpetuated to the point where they have lost all meaning. For instance, I have encountered practical varnish makers who have learned the trade as apprentices to men of older generations, who insisted upon throwing a slice of bread or a handful of feathers into each batch, and according to their notions no varnish could be good without these additions—though they could not explain why. This is merely the survival of a sensible procedure of an earlier day, when thermometers were not in general use in varnish kettles; an expert varnish cooker could judge and control the heat of the oil or varnish by observing the charring of such materials, which were eventually strained out and which had nothing to do with the quality of the product.

Formulation. Formulation involves combining materials in definite proportions and manner so as to utilize the desirable qualities of each, to overcome or neutralize undesirable qualities, and to create a product whose properties will best meet the requirements for which it is intended. It is one of the most important applications of the knowledge of the properties of materials. General rules governing the behaviour of any class of materials cannot always be applied to every member of the class; the properties of individual substances and their alteration when mixed with other materials must be learned from experience as well as from a study of the basic principles which govern chemical and physical behaviour.

Some materials may be added to a mixture in undefined amounts, whereas other combinations of materials require exact measurements, and often the manner or sequence of the addition is important. In some cases there will be a little leeway as to accuracy of measurements, and published recipes should always indicate this; most of the successful, standard formulas are the results of careful development and are to be followed with accuracy.

When a recipe calls for '3 to 5 parts' of a material, this should not be taken to mean that it does not matter what quantity between these limits

one throws in; rather, it means that according to the special properties required, an individual will find somewhere within this range the amount needed to give him best results. If a writer states that a little turpentine added to a paint will improve its working properties, he expects the reader to have sufficient experience with the materials to add an appropriate amount, and to realize that too little will not accomplish the purpose and that too much may overdilute the mixture and weaken the resulting film. On the other hand, if a number of various ingredients are listed in exact amounts with explicit instructions for their combination, the assumption on the part of the reader should be that here is a recipe that has been worked out to give definite results, and that it must be followed accurately. Whether or not it can be adjusted or altered to fit different circumstances or special requirements in individual cases, can be determined by trials.

In any experimental or testing work it is truly necessary to preserve accurate detailed records of all work done, including dates, sources of materials, and all other relevant data. Materials, whether put into use or put away to age, should be well identified either by being labelled with detailed descriptions or by serial numbers referring to descriptions in a notebook. Painters who have spent much time in experimental work on materials often find that after a few months or years the results of careful and interesting work are useless because of the absence of records.

The conversion tables on pages 422–4 may be used to change figures from one system of weights and measures to another; where the formula is written in pounds or gallons, quarts, and pints, and it is desired to reduce these to ounces in order to make small lots (especially when multiple experimental batches are to be made), the pounds figure can be converted to ounces by multiplying by 16, the gallons figure to fluid ounces by multiplying by 128, the quarts figure, by 32, and the pints, by 16. A recipe calling for 5 pounds of a dry material to 1 gallon of a liquid would then read 80 ounces to 128 fluid ounces; to make about 4 fluid ounces, which is a convenient small batch, find the figure which will divide all the amounts into conveniently measurable figures near that amount; in this case it would be 32, which gives a resulting recipe of $2\frac{1}{2}$ ounces to 4 fluid ounces. To alter the strength of a solution of known percentage, the calculations noted on page 426 may sometimes be used.

The modern recipe books of miscellaneous technical formulas are sometimes valuable; usually they are more helpful as sources of hints for experimentation than as sources of ready-made, usable formulas. Some of the best of these compilations of miscellaneous technical recipes are listed in the bibliography.[89ff]

Some recipes call for the melting of inflammable materials, and when these are followed, precautions should be taken to prevent accidental ignition; also provisions for the control of a fire must be considered in advance. Melt as small a batch as is convenient, keep the space around the stove clean and clear, and use a metal or asbestos plate between the vessel and the gas flame or electric coil. Sand or a Pyrene extinguisher will put out small fires;

water is likely to make grease or oil fires spread, although enough water in one good dousing will put out any fire except burning benzine or other similar volatile liquids. A stirring rod is likely to make a small can tip over. A flat cover larger in diameter than the can or pot will smother a small fire. Never heat mixtures which contain inflammable volatile solvents over a direct flame. When a molten wax or resin is thinned with volatile solvent, a large percentage of the first addition passes off in the form of vapour; therefore, even in the case of the less inflammable solvents such as turpentine or kerosene, all such thinning must be done away from the stove or other flame, and with good ventilation. All waxes may be melted in a water bath, but mixtures with resins will ordinarily require direct heat.

Mixing of Smooth Pastes. Various powders and liquids require different methods of mixing to produce pastes free from lumps; some recipes indicate the correct procedure. In the case of the usual paint the vehicle is poured gradually into the pigment in a container, with continual stirring, to produce a stiff, smooth paste, the last part of the liquid being added after this stage has been reached. When small amounts are made on the slab with palette knife and muller, or with a mortar and pestle, the same procedure is followed: the paste is kept stiff until free from lumps, after which it is thinned to the final consistency. Gesso is mixed in the same way except that such a high degree of smoothness is not required; it is usually strained or squeezed through cheesecloth, which disperses minor lumps. Materials such as flour, starch, casein, etc., are mixed in the reverse manner, because they are acted upon by the water, and some solution or swelling to form a colloidal mass is involved. Starch or flour paste is commonly mixed by sifting the dry powder into hot water gradually in three or four successive portions, stirring continuously and mixing to a uniformly well-suspended condition before adding the next portion. Materials which tend to repel wetting are made into a stiff paste by continued stirring with a round rod in a container, or by mulling.

Weights and Measures

If one does a great deal of work on formulas and home-made products, it is advisable to have a scale or balance capable of weighing out small amounts of dry materials with a fair degree of accuracy. Small balances, adequate for most purposes, can be bought at moderate cost; fine ones of high accuracy are expensive. Second-hand scales originally intended for various uses can sometimes be picked up.

Persons who have but occasional use for weights may have portions of materials weighed out at a shop; many users of home-made products prefer to measure as many of their materials as possibly by volume. Because materials vary as to size of lumps or particles, etc., and because some formulas call for extreme accuracy or for very small portions, this is not always feasible. The recipes quoted in this book mention volume measurements whenever they may be used. Measuring glasses of the following sizes will be found useful:

1 quart, graduated in ounces.
1 pint, graduated in ounces.
2 ounce, bell- or cone-shaped, graduated in drams (⅛ fluid ounce). Also obtainable with additional scale in millilitres (cubic centimetres).
Cylinder graduated in millilitres (c.c.), capacity 25, 50, 100; or any larger size, depending upon requirements.
For very small, accurate amounts of liquids, especially in small-scale experimental batches, a Mohr's pipette, 10 ml. capacity, graduated in tenths. A large choice of measuring glasses will be found at laboratory supply houses.

A handy means for measuring approximate small volumes and proportions of pigments, pastes, and other dry and fluid materials is a set of aluminium kitchen measuring spoons: tablespoon, teaspoon, half and quarter teaspoons (3 teaspoons = 1 tablespoon; 25 quarter teaspoons = 1 fluid ounce; 1 quarter teaspoon = 1% of 4 fluid ounces). When using these for dry powdered material, one should fill them without packing or tamping the powder in, then level it off with a palette knife. These measurements are occasionally referred to in the recipes. Throughout this book the terms fluid ounce or ounce by volume have been used to distinguish the ounce by volume from the avoirdupois ounce, which is simply called ounce. The list on page 425 showing fraction and decimal equivalents may be used to convert a decimal number in a weight or measure to its approximate fraction.

British Systems

Linear

Inches (*ins. or* ″)	*Feet* (*ft. or* ′)	*Yards* (*yds.*)
12	1	
36	3	1
198	16½	5½

Area

Square inches	*Square feet*	*Square yards*
144	1	
1296	9	1

Volume

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
1 cubic foot = 7·48 gallons.
A cubic foot of water at 62° F. weighs 62·2786 pounds.

WEIGHTS AND MEASURES

Liquid Measure (Capacity)

Ounces (fl. oz.)	*Gills*	*Pints (pts.)*	*Quarts (qts.)*	*Gallons (gals.)*	*Cubic inches (cu. ins.)*
4	1				
16	4	1			28·9
32	8	2	1		57·75
128	32	8	4	1	231·

1 British Imperial gallon = 277·3 cubic inches = 1·2 U.S. gallons.

1 gallon of water at normal temperature weighs 8⅓ pounds; a pint weighs about a pound.

Apothecaries' Measure

Minims	*Fluid drams*	*Fluid ounces*	*Pints*	*Gallons*
ℿ	f℥	f℥	O	G
60	1			
480	8	1		
7680	128	16	1	
		128	8	1

The ounce, pint, and gallon are the same as in ordinary liquid measure.

Weight (Mass)

(The grain is the same in the three systems following.)

Avoirdupois (Commercial or Customary System)

Grains (gr.)	*Drams (dr.)*	*Ounces (oz.)*	*Pounds (lbs.)*
27·34	1		
437·5	16	1	
7000	256	16	1

Troy Weight

(Used by jewellers and refiners of precious metals)

Grains (gr.)	*Pennyweight (dwt.)*	*Troy ounces*	*Troy pounds*
24	1		
480	20	1	
5760	240	12	1

1 lb. troy = ·823 lb. avoirdupois

1 carat = 3·2 grains

Apothecaries' Weight

(Used by pharmacists, physicians, and in some special technical processes)

Grains (gr.)	*Scruples* ℈	*Drams* ʒ	*Ounces* ℥	*Pounds* lb
20	1			
60	3	1		
480	24	8	1	
5760	288	96	12	1

Metric System

Universally used in science, and for common purposes in Europe and Latin America; many efforts to reform the English and American systems in common use to conform with the metric system have failed, because long usage has rooted those systems in our culture.

Length

1 millimetre = ·001 metre (mm.).
1 centimetre = ·01 metre (cm.)
1 decimetre = ·1 metre
1 metre.
1 dekametre = 10 metres.
1 hectometre = 100 metres.

Weight

1 milligram = ·001 gm.
1 centigram = ·01 gm.
1 decigram = ·1 gm.
1 gram (gm.).
1 dekagram = 10 gm.
1 hectogram = 100 gm.
1 kilogram = 1000 gm.

Volume (Capacity)

1 millilitre = ·001 litre = 1 cubic centimetre (ml. or c.c.).
1 centilitre = ·01 litre.
1 decilitre = ·1 litre.
1 litre (= 1 cubic decimetre = 1000 ml.).
1 dekalitre = 10 litres.

Conversion Factors

Weight

To convert	*to*	*multiply by*
pounds (avoirdupois)	grams	453·6
	kilograms	·45
	troy pounds	1·22
grams	grains	15·43
	drams	·56
	troy drams	·26
	ounces	·0353
	pounds	·0022
grains	grams	·0648
	drams	·0357
	ounces	·00229
	pounds	1/7000
ounces (avoirdupois)	grams	28·35
	grains	437·5
	pounds	1/16
	troy (or apothecaries') ounces	·91
	troy pounds	·076

CONVERSION FACTORS (*Continued*)

To convert	*to*	*multiply by*
ounces (avoirdupois)	pennyweight	18·23
	troy (or apothecaries') drams	7·29
troy pounds	pounds (avoirdupois)	·823
	kilograms	·373
	ounces (avoirdupois)	13·17
troy or apothecaries' ounces	ounces	1·1
	drams	17·5
	pounds	·069
	pounds (troy)	1/12
kilograms	drams	564·38
	grains	15432·4
	ounces	35·27
	ounces (troy or apoth.)	32·15
	pounds	2·3
	pounds (troy)	2·7

Fluid Measure (Capacity)

fluid ounces (B.S. and apothecaries')	millilitres	29·57
	fluid drams	8
	litres	·03
	cubic inches	1·8
	gallons	1/128
litres	pints	2·11
	quarts	1·06
	cubic inches	61·025
	fluid drams	270·5
	gallons, U.S.	·26
	gallons, Imperial	·22
	fluid ounces	33·81
gallons	cubic feet	1·34
	gallons, Imperial	·833
	litres	3·785
	ounces	128
	millilitres	3785·4
fluid drams	millilitres	3·7
	fluid ounces	·125
	cubic inches	·2256

CONVERSION FACTORS (*Continued*)

To convert	*to*	*multiply by*
fluid drams	pints	·0078
	quarts	·004
millilitres (cubic centimetres)	fluid drams	·27
	minims	16·23
	fluid ounces	·0338
	cubic inches	·061
	pints	·0021
	quarts	·001
pints	millilitres	473·179
	cubic feet	·017
	cubic inches	28·9
	gallons	·125
	litres	·473
	minims	7680
quarts	millilitres	946·36
	cubic feet	·033
	cubic inches	57·75
	fluid drams	256
	gallons	·25
	litres	·946
	Length	
inches	millimetres	25·4
	centimetres	2·54
	metres	·0254
metres	inches	39 37
	feet	3·28
	yards	1·09
	centimetres	100
centimetres	inches	·3937
	feet	·0328
millimetres	inches	·03937
	feet	·00328
feet	centimetres	30·48
	metres	·305

Obsolete: 1 ell = 45 inches or 114·30 cm.; 1 cubit = 18 inches or 45·72 cm.

Equivalents of Fractions and Decimals

·0156	$\frac{1}{64}$	·3125	$\frac{5}{16}$
·0312	$\frac{1}{32}$	·3333	$\frac{1}{3}$
·0500	$\frac{1}{20}$	·3750	$\frac{3}{8}$
·0555	$\frac{1}{18}$	·4375	$\frac{7}{16}$
·0625	$\frac{1}{16}$	·5000	$\frac{1}{2}$
·0714	$\frac{1}{14}$	·5625	$\frac{9}{16}$
·0833	$\frac{1}{12}$	·6250	$\frac{5}{8}$
·1000	$\frac{1}{10}$	·6666	$\frac{2}{3}$
·1111	$\frac{1}{9}$	·6875	$\frac{11}{16}$
·1250	$\frac{1}{8}$	·7500	$\frac{3}{4}$
·1666	$\frac{1}{6}$	·8125	$\frac{13}{16}$
·1875	$\frac{3}{16}$	·8750	$\frac{7}{8}$
·2000	$\frac{1}{5}$	·9375	$\frac{15}{16}$
·2500	$\frac{1}{4}$		

Approximate Equivalent Volumes of White Lead in Oil

Weight	*Volume*
100 pounds	$3\frac{1}{4}$ gallons
50 ,,	$1\frac{5}{8}$,,
25 ,,	$6\frac{1}{2}$ pints
$12\frac{1}{2}$,,	$3\frac{1}{4}$,,
5 ,,	$1\frac{1}{4}$,,
1 ,,	1 gill

Density—Specific Gravity

The *density* of a substance is the relation between its weight and volume—for example, the number of pounds to a gallon. This is the usual standard in industrial or technical work; in science the gram and millilitre are used, and the density of a substance is expressed in grams per millilitre. One millilitre of pure water weighs one gram.

The *specific gravity* of a liquid or solid is its weight divided by the weight of an equal volume of water; thus the specific gravity of linseed oil, which is lighter than water, will run around ·933, and the specific gravity of carbon tetrachloride, which is heavier than water, is 1·59. The specific gravity of distilled water is 1 at 4° C.

Hydrometry. A simple and easy method for determining the specific gravity of a liquid is to use a hydrometer, which is a slender sealed glass tube bearing graduated marks and weighted at the bottom. The liquid, at normal room temperature (70° F.) or at any special temperature to which the instrument may have been calibrated, is poured into a glass cylinder of convenient size, and the hydrometer is carefully immersed in the liquid and allowed to float in it freely, whereupon the specific gravity is read directly from the mark which coincides with the surface of the liquid when the

hydrometer is at rest and floating clear of the walls of the cylinder. Measurements of extreme accuracy and comparisons of slight variations in specific gravities can be obtained only by experienced technicians and by the use of more precise apparatus. For accuracy and convenience, hydrometers are usually made with a small range, suitable for use in one type of solution or liquid.

In general technical practice, it is customary to use hydrometers marked with the Baumé scale instead of the less convenient specific-gravity scale; there are two Baumé scales, one for liquids lighter than water, and one for liquids heavier. If it is necessary to convert Baumé figures to specific-gravity figures and vice versa, a conversion table should be referred to. These are widely available and are published in all of the chemical handbooks and many technical works.

Calculations for Altering the Strength of Solutions *

The following methods are universally accurate by weight; when amounts by volume are taken (especially when the solutions are weak or when there is not too great a difference between strengths), the results will be sufficiently accurate for most technical purposes. When absolute accuracy is necessary in volumetric work, as in carefully controlled laboratory procedure, the correct volumes are calculated by dividing the weight amounts by the specific gravity of the solutions $\left(\frac{\text{mass}}{\text{sp. gr.}}\right)$.

1. To dilute a solution of known strength to any required amount of lower-percentage concentration, divide the lower-percentage number by the higher, and multiply the quotient by the amount of weaker solution desired. The result will be the amount of original solution which must be mixed with sufficient water (or other solvent) to produce the amount of weaker solution desired.

For example, to make 16 ounces of a 4% solution of formaldehyde from the 40% solution in which it is commonly sold, divide 4 by 40, which will give 0·1; multiply this by 16. The result, 1·6 ounces, is the amount of 40% formaldehyde solution to be mixed with enough water (14·4 fluid ounces in this case) to produce 16 ounces of 4% solution.

2. To dilute a given amount of solution of known strength to any weaker concentration by adding water to it, subtract the lower-percentage number from the higher, divide this difference by the lower number, and multiply the quotient by the amount of liquid to be diluted. The result will be the amount of water required to produce the weaker concentration when mixed with the original amount of the stronger.

* Adapted from *Chemical Calculations* by *R. Harman Ashley*. New York, Van Nostrand, 1927. This book contains a complete account of calculations of this kind. Other simplified methods for altering the percentage composition of solutions and dry mixtures can be found in Olsen[93a] under 'Rectangular method for the dilution and concentration of liquids and mixtures', and *Stevens' Arithmetic of Pharmacy* by C. H. Stocking and J. L. Powers (New York, Van Nostrand, 1937), under 'Alligation'.

For example, if one has 10 fluid ounces of 40% formaldehyde to be diluted to a 4% solution: $40 - 4 = 36$; $36 \div 4 = 9$; $9 \times 10 = 90$; which is the number of fluid ounces of water to add to the 10 fluid ounces of formaldehyde to produce the 4% solution. In this case, the ratio happens to be in round numbers, 9 to 1, and any convenient amount could be made by using these proportions.

BRUSHES

The hairs and bristles which are used in the manufacture of brushes vary greatly in quality, the best ones being expensive and not common on the market; but the greatest element in brush making is skilled, expert workmanship. A superlatively good brush is a great asset in painting, and most artists find that a few good brushes will serve their purposes better than a large variety of inferior ones. The very smallest sizes have their uses for certain types of work, but the most approved rule in the average technique is to use the largest brush which is capable of producing the fineness or delicacy of line required. For the finest sort of line the extreme tip of the brush is used, and a well-pointed No. 3 or 4 in the hands of a competent painter will in most cases be more advantageous than the 0 or 00 sizes. Its use is universally held to be more conducive to vitality and character, and its greater versatility is unquestioned. The mature painter's choice of brushes, however, is entirely a matter of personal preference, and no definite rules should be laid down; the statements here are merely to indicate the general characteristics which different types of brushes display.

The flat brushes with flattened ferrules are a comparatively modern invention; although such shapes were known and occasionally used for certain purposes from the earliest days, they did not come into general use until the middle of the nineteenth century; today they are used to a greater extent in oil painting than are the rounds. Those with short-length bristles are called brights, and those with longer bristles are flats. The length of brights is, or should be, about $1\frac{1}{2}$ times their width; flats are thicker and their length is about $2\frac{1}{2}$ times their width. Chisel brushes which are more or less bevelled to a comparatively sharp edge are a further refinement, and they are usually obtainable only in the best grades. Many of the characteristic effects produced in older paintings by free brush stroking with round brushes are unsuccessfully sought after by painters who are experienced only with flats and brights. The flat brushes are more popular than rounds because of their greater versatility, different strokes being produced according to the angle at which the brush is held. The finest-quality bristle brushes for oil painting are made of imported white hog bristles, and in the flat shapes the corners are curved toward the centre naturally—that is, curved bristles are used at the outer edges. The best soft brushes for oil painting are made of red sable; the second best, of the so-called Russian sable (fitch).

For water-colour use, writers and instructors have cautioned painters to avoid brushes with concave tips; some warn against brushes with too much belly; for others, brushes can never be fat enough. It will be noted that when

wet, the finest-quality hair brushes show no sign of concavity between the point and the fullest part of the brush, while the cheapest ones are almost always concave at this place. Most painters agree on the desirability of using the largest-sized brushes with which the desired manipulations can be performed.

Red sable (kolinsky tail) has the proper combination of softness, flexibility, springiness, and durability, and when hair of the highest quality is used and the best workmanship is employed, it makes the best brush for normal water-colour work. Hairs of uniform thickness and proper length must be chosen by the makers, and correctly formed and held in the ferrule at the right point; if they are inserted too far the brush will be over-springy and harsh; if they are not inserted far enough, the brush will be too soft. Camel-hair brushes (actually made from nearly every kind of animal except camels; the best grades are made from squirrel tails) are too soft and have not sufficient elasticity or 'life' for average professional purposes, yet this quality makes them desirable for some special manipulations. An inferior grade of sable is generally preferable to camel hair. Ox hair is cheaper than red sable and generally inferior, but its rigidity makes it desirable for some uses.

One may sometimes discover brushes of high quality among those mounted in quills instead of in metal ferrules. In the early days of painting all hair brushes came in quills and were called hair pencils, but today the quill brushes are made only for a few special purposes; they are sold under several systems of designation.

The Japanese and Chinese brushes in reed handles are obtainable in a number of styles and are well liked by some artists; others are unable to use them. The sensitive character of line and the versatility of effect which they will produce, show their value when employed in trained hands. Their characteristics, as a general rule, are those of the camel-hair brush.

A useful brush for the application of flat water-colour washes is a ¾- to 1-inch flat-stroke lettering brush of best quality red sable or ox hair. O'Hara,[47] whose books deal with the direct, bold sort of water-colour painting, recommends it for nearly all purposes, and he demonstrates its use in a series of illustrated instructions and training exercises. Strokes of considerable delicacy and variety can be obtained by using the edge, and if, instead of slanting the brush as one would a pen or pencil (which would cause the hairs to bunch up and make a line wider than the chisel edge) one leans it in the direction opposite to that of the stroke so that its right-hand or leading corner does not touch the paper, the hairs of the left side will trail out singly and produce a very thin line. A solid covering stroke on rough or roughish paper is made by holding the brush vertically to the paper and stroking with the width of the brush; the same result can be obtained with the brush held at a 45° angle if the stroke is made very slowly. By drawing this same 45° stroke rapidly across the paper, a broken, sparse, or dry-brush effect is produced, even with a well-filled brush. A slightly different broken effect can be obtained by holding the brush at more of an angle—even flat against the paper.

A number of clean, dry brushes are required for certain manipulations,

such as the application of flawless glazes and other careful work in oil painting. If a brush is cleaned in turpentine, wiped off, then rinsed in a cup of quick-drying solvent such as acetone or ethyl acetate and flicked on cloth with a light, dusting motion, or its handle twirled rapidly between the palms of the hands, it will become dry at once and be sufficiently clean to continue most operations. The number of brushes required may thus be kept at a minimum.

There is only one correct way to clean and preserve paint brushes of any kind. Immediately after use, the paint or varnish should be thoroughly rinsed out with the appropriate solvent, and the brush shaken or wiped with a cloth, then washed well with warm water and a cake of common yellow household soap, great care being taken to rinse out all traces of soap under running warm water. Brushes which have become stiffened with shellac may be washed in borax solution. Those upon which oil paint has hardened and which require cleaning with paint remover, trisodium phosphate, or prepared brush-softener, lose much of their life. When simple-solution varnishes dry on a brush they cause less damage than do oil paints, and are usually removable with their solvents. However, the rubber, glue, or resinous setting of brushes is often weakened by such treatments. When a clear, simple-solution varnish such as damar is washed out with soap and water, a white, soapy residue sometimes clings to the base of the bristles and leaves the brush in a generally unsatisfactory condition for future use as a picture-varnishing brush. If picture varnishing is frequently done, a brush should be reserved exclusively for the purpose (see page 356); it can be kept in a soft or easily softened condition (provided it is not stored for too long a period) by washing it out well in several fresh changes of its solvent and folding a piece of kraft paper tightly around it in a manner similar to that in which new varnish brushes are packed. One make of varnish brush is sold wrapped in a durable jacket of strong fibre paper with a twine fastening.

House painters' brushes which are in continual use are sometimes kept suspended in a can of linseed oil or half oil and half pure turpentine after being rinsed. Brushes left in containers in this manner must never lean against or touch the sides or bottom of the vessel. A clean, dry brush stored in a closed box or drawer will keep better than one left suspended in liquids. When brushes are stored for any long period of time, it is usual to put camphor, naphthalene, or paradichlorobenzene in the box as protection against moths.

Palettes

The conventional wooden palette is not so universally employed as it was in the recent past. Its brown colour served without many disadvantages up to the days when painters adopted a new attitude in regard to the relation of their colour keys to the colours of nature, at which time a cleaner or paler background for mixing colours became necessary. The traditional oval palette of graceful curve is sometimes used by painters because of custom when a

solid table next to the easel would better serve the purpose and leave the hands free.

There are many cases, however, where a light-weight palette held in the hand is necessary for the proper execution of the particular techniques. For this purpose, the white lacquered aluminium palette which was originally intended for use with aqueous mediums can be employed, as well as the regular traditional wooden palette, which may, if desired, be coloured white by the artist. The insolubility of shellac in oils, turpentine, and mineral spirit makes it useful for such coatings; white pigment may be stirred into the shellac to colour it. The wetting power of alcohol makes it unnecessary to grind or mull the pigment for this purpose. Where a more universally resistant coating is required, the shellac may be replaced by white lacquer. Such palettes must be kept especially clean and no oil colours should be allowed to dry on them, because the removal of old dried paint will usually require solvents which will remove the shellac or lacquer surface. The white pigment may be tinted to a cool, neutral, or warm tone if desired.

The modern tendency is to work from a scrupulously clean palette and waste remnants of paint rather than allow them to accumulate. Glass and china plates are easily cleaned of hardened paint by scraping them with a razor blade, with or without softening the paint with solvents. A badly stained ground glass or stone slab can be scoured by grinding pumice and turpentine on it with a muller.

Some artists collect and use numbers of plain white dishes and small porcelain, glass, or tin vessels of little or no value, so that they may be thrown away without much loss in case the accumulation of paint or varnish gets beyond the point where they are worth saving. This follows an old procedure; painters from the earliest times have used sea shells of various types in the same way. Light-weight dishes made of plastic ware are convenient, especially for mural work. However, the majority of painters prefer a palette arrangement in which the depressions are not so deep and not so completely separated from one another that the colours cannot be rapidly and easily taken up and scrambled together with the brush when desired.

Inks

Chinese or Indian Ink. The description of India ink in the general pigment list gives the principal ingredients of the material, yet it is a crude description in view of the traditional Chinese and Japanese products, which are most complex mixtures, involving a number of minor additions and manipulations both for ceremonial reasons and to impart further brilliancy, working qualities, and delicacy and range of tone. The native painters have always been exacting connoisseurs on the subject, demanding their favourite brands, whose histories are often long and distinguished and whose manufacture continues in establishments where the processes have been handed down for centuries. These inks are sold in little sticks which are rubbed with water on

stone blocks or in shallow mortars; even the manner of rubbing is said to influence the delicate character of the ink.

Liquid India ink has practically replaced this material in modern usage; it is sold in two varieties: the waterproof, which will withstand washes after it has dried, and the soluble, the dried film of which may be washed away by going over it with water. The latter kind is usually more applicable to fine lines and delicate manipulations and effects. Both may be freely diluted with water while in the liquid state. The inks which become insoluble in water after drying are usually made with a water solution of shellac and borax.

Coloured Inks. Coloured drawing inks are carefully formulated to meet every requirement except that of absolute permanence; although lightproof pigments may be employed in a few instances, the coloured inks can never be relied upon for other than temporary results, and should not be used for permanent artistic work.

Writing Ink. The principle upon which the composition of writing ink is based is the action of atmospheric oxygen on an acid mixture of iron salts and tannin, a material which is obtained from an infusion of nutgalls. Modern writing ink is made by combining tannic, gallic, and dilute hydrochloric acids with an iron salt, phenol, and a blue or black dye. The dye is used to make the ink visible at once because the reaction between the oxygen, iron, and tannic acid is not completed for a day or two, and the fresh writing would not be satisfactorily visible without dye. The best modern writing ink is a carefully balanced mixture of ingredients, designed to have the best flowing properties and least corrosive action on pens and paper, and to give the most permanent results. Many modern proprietary writing fluids of special characteristics are inferior to the standard black or blue-black iron gallotannate ink. Iron gallotannate writing inks have been in use since the twelfth century; all of their properties have been standardized and greatly improved in recent years. Their permanence, however, is not usually considered great enough for general artistic use, especially where there is continual exposure to daylight; permanence for use in records and documents, which are ordinarily kept filed away in darkness and in which considerable fading or colour change could occur without seriously impairing legibility, is another matter.

Ink for writing and drawing was invented in China and Egypt about the same time; according to various discoveries, the date in each country is generally believed to be not much before 2500 B.C. These inks were of the same type as our modern India or Chinese inks—mixtures of carbon with binders (gums, glues, etc.) The later Roman ink was principally sepia. The earliest record of the material we now know as writing ink, as it has been made and used from medieval times down to the present, is in the writings of Theophilus, who described an iron-nutgall ink. Pliny, however, about ten centuries before this, knew that paper treated with copperas could be blackened with an infusion of nutgalls.

Glossary of Some Miscellaneous Terms

This list is made up of some of the words and terms used in art and its technology. Others will be found in the index.

AGGREGATE. The coarse or inert ingredients which are mixed with cement in the making of concrete.

ARRICACCATO. In fresco practice, the plaster coat which underlies the final painting coat; traditionally composed of lime and sand. Term not in general use.

B.P. Where these letters follow the name of a material they indicate that the material conforms to the specifications of the British Pharmacopoeia, and that it is approved for use in medicinal preparations. This grade is usually below the C.P. grade in absolute chemical purity, but of more than adequate purity for average technical use. Corresponds to the American USP.

BASE. An inert pigment used in the manufacture of lakes. In chemistry, an alkaline or alkaline-forming substance.

BLOOM. A foggy, whitish (or blue-white), dull surface effect which forms on varnished pictures or other varnished objects.

BLUSH. Bloom. The term is usually applied to bloom on cellulose lacquers, and more often implies a basic or internal defect than a surface condition.

CAMAÏEU. A technique of painting in monochrome, using two or three tints of the same pigment without regard to local or realistic colour.

C.P. Chemically pure, or a grade of material as free as possible from all traces of impurities. Sometimes applied to commercial pigments to describe a grade free from extender or added inert pigment.

CHIAROSCURO. A technique of pictorial representation wherein objects are brought out strongly by the use of black or any dark colour and white, generally in bold contrast; the entire picture is usually dark, relieved by white accents. Also an element of this effect in any picture.

COVERING POWER. The extent of the area over which a given amount of liquid paint or varnish will spread to give a satisfactory coating when it is applied in a normal layer, ordinarily expressed in square feet per gallon. Sometimes confused with hiding power.

DISTEMPER. A term employed to designate aqueous paints made with a simple glue-size or casein binder, such as are used for flat wall decoration and for scenic and poster colours. Among the products which may be classified under this heading are cold-water paints, and show-card and poster colours. The term is rather more descriptive of bulk or house paints than of artists' paints.

DOCTOR. A scraper or knife-edge used to scrape off paste or paint from a surface.

ENAMEL. (1) A vitreous glaze or porcelain which contains pigments, applied

to metal or pottery objects and fused to produce a smooth, hard, durable surface by heating in a kiln or furnace.

(2) An object so decorated.

(3) A liquid paint which dries with an extremely high gloss, its effect approaching that of a vitreous enamel.

EMBU (French). In an oil painting, a dull spot in an otherwise glossy surface, caused by a sinking-in of the oil colour. Term not in general use.

FILLER. See inert pigment.

FIXATIVE. A dilute varnish which is applied by a sprayer or atomizer to bind the loose particles of charcoal, pastel, or crayon pictures and prevent them from rubbing off. A fixative differs from a varnish in that it serves only one purpose, that of binding the particles in a weak surface manner; it does not lock them into an impervious film. To accomplish this function, it would have to be so concentrated that it would have an undesirable optical effect on the picture. (See page 225.)

FROTTIS (French). A thin wash of paint, especially a transparent or translucent one; also a glaze or scumble. Term not in general use.

GANOSIS. The toning or dulling of stone sculpture—for instance, by the application of colours mixed with wax.

GESSO. A solid coating made with a purely aqueous binder, either glue, casein, or gelatin solution. It is usually pure white in colour, and the dry ingredient is either whiting, chalk, or slaked plaster of Paris, sometimes with an addition of heavier white pigment to increase the whiteness or opacity. Gesso is used as a painting ground by applying it in liquid form with a brush, or as a putty and modelling material, in which case it is made into a stiffer, plastic paste. The word was used by the craftsmen of the Italian Renaissance and is an Italian form of the Latin *gypsum*.

GRISAILLE. A technique of monochrome painting in two or three shades of grey, as in the imitation of a bas-relief. Also a rough grouping into one class of all methods of painting which differ from a simple direct technique; more specifically, the method of painting in full modelling in black and white or other simple contrasting tones, and applying transparent colour over this in thin layers or glazes. Also the name of a pigment used in glass painting. (See page 50.)

HALF CHALK (HALF OIL) GROUNDS. Emulsion grounds. Grounds made of chalk and glue are universally known as gesso grounds in England and America; I should interpret the German term *Halbkreide* as 'semi gesso' rather than 'half chalk'.

HIDING POWER. Degree of opacity in a paint or pigment; ability to mask or conceal an underpainting. The term covering power is sometimes confused with it.

HYDROFUGE. A means of removing moisture; a substance or apparatus so used.

HYDROPHILE. A substance which has an affinity for, or will attract water.

HYDROPHOBE. A substance which repels water.

HYGROSCOPIC. Having the property of absorbing and holding moisture when exposed to the air.

IMPASTO. Thick, heavy painting; usually oil painting composed of pronounced bristle-brush strokes or palette-knife applications, which stand out in relief and are plainly apparent to the spectator.

IMPRIMATURA. A veil or thin glaze of colour applied to a ground as a preliminary coating. Term not in very wide use.

INERT PIGMENT. A finely powdered substance, which when mixed with a coloured pigment causes no appreciable change in its shade or hue. Although inert pigments are used largely as adulterants or cheapeners, many of them are also employed to impart valuable or desirable physical or structural properties to paints and other mixtures, (See page 89.)

INTONACCO. The final layer of lime plaster upon which a fresco is painted. Term not in general use.

JAPAN. A loose term applied to two classes of varnishes: (1) Varnishes which are mixed with paints in order to impart a gloss. These are generally composed of resins and solvents with little if any oil, and are too brittle to be used alone. (2) Decorative Japans. These are cheap enamels, almost always black, and almost always containing asphaltum. Used to decorate articles made of sheet iron and other metals. Some Japans dry in the air and others require baking.

JAPAN DRIERS. A confusion of terms. Sometimes the materials referred to are varnish-paints which contain added liquid driers; more often they are resinate driers in solution having no properties in common with the Japans described above. Japan colours sold in tubes and cans are ground in a quick-drying, resinous varnish which contains little or no oil; they are intended for tinting and underpainting purposes in industrial work, where a high oil content would be undesirable, and for quick-drying sign painting and similar decorative work which is to be protected with a layer of clear, durable varnish. They are not to be used in permanent painting.

LIPO. Prefix signifying oil or fat. Lipophile: a substance which has the property of attracting fats or oils, or a selective affinity for oil over water. Lipoid: a material belonging to a specific group of chemical compounds which resemble fats or waxes in many of their properties.

LOCAL COLOUR. The true or actual colour of an object as distinguished from the colour effect it produces when viewed as part of a whole composition or when influenced by light or atmospheric conditions in nature or, in a painting, by the technique and intentions of the painter.

MAROUFLAGE. Process of affixing canvas to a wall by means of a cement, traditionally white lead ground in oil.

MEDIUM. (1) The liquid constituent of a paint, in which the pigment is suspended, or a liquid with which a paint may be diluted without decrease in its adhesive, binding, or film-forming properties. (See vehicle.)

(2) The mode of expression employed by an artist: etching, painting, sculpture, etc.

(3) The actual instrument or material used by an artist: oil paint, chisel, needle, etc.

In general usage, the plural form of (1) is most often mediums, that of (2) and (3), media.

OCCLUSION. The surrounding of isolated particles of a substance by a solid or semi-solid. Absorption or adsorption of gases by a solid.

PALETTE. Besides being used to refer to the implement upon which a painter holds or mixes his colours, this term is employed to denote a selected assortment or limited group of colours, chosen for use in a painting technique.

PLASTICIZERS. Substances added to varnishes, lacquers, and paints in order to impart or maintain necessary properties or correct undesirable characteristics. The term is most often used in connection with products which impart flexibility and overcome a natural tendency toward brittleness, but it is also applied to materials which improve brushing qualities, adhesion, compatibility with pigments, etc. When used to impart permanent film qualities, plasticizers should be non-volatile.

SPACKLING OR SPARKLING (probably from the German *spachteln*, to putty up). The rectifying of a defect in plaster or a mural painting by digging out of the defective spot and filling it in with a plastic gesso, plaster of Paris, Keene's cement, or other similar material.

SUB-STRATUM. Base (as applied to lakes or let-down pigments). Also underlayer. Term is obsolete in English but current in other languages.

TACK OR TACKINESS. Adhesive stickiness, such as that of the surface of incompletely dried varnish.

TEMPER. This verb is familiar through its use in referring to a conditioning process such as the heat-treatment of steel and other materials, whereby strength, flexibility, ductility, or other desirable properties are imparted. As applied to paint technology, the term has never had any wide usage in America, but in European writings, both old and modern, it has been employed to denote the conversion of an intractable, non-plastic substance into a material that has desirable properties for the purpose for which it is intended. In this sense, tempering would include making dry colours or stiff paste paints brushable, permanently adherent, etc., by adding the proper medium or liquid, making a brittle or unyielding substance flexible or ductile, or imparting any good quality to a non-plastic material by the use of a liquid, a wax, etc. Our word tempera (see page 165) has the same derivation and was used in early Latin and Italian writings to mean any liquid medium with which pigments could be combined to make a paint, the resulting product being distinguished from fresco paint, which contained no added medium. Later the word was applied specifically to work done with egg-yolk; after other materials were developed, the term came to include, as it now does, all painting

techniques that employ emulsions, and sometimes (but not accurately) any aqueous opaque paint as distinguished from oil paint.

TESSERA. A small tile or stone; one of the units of a mosaic.

TOOTH. A slight roughness or coarseness in the surface of a dried paint film or painting ground, which assists in the application and bonding of a subsequent coat of paint.

TRACTION. A defect of paint or varnish coatings, where the film cracks and the edges of the cracks recede to form wide, open fissures, disclosing the underlying surface. Colloquially called creeping or crawling.

TRULLISATIO. The first coarse undercoat of fresco plastering. Term not in common use.

VEHICLE. A liquid used as the carrier of pigments in a paint; the term is interchangeable with medium, but is perhaps more properly applied to the liquid used as an ingredient in manufacture than to a liquid added during painting procedure.

VERDACCIO. A dark greenish colour used in underpainting, outlining, or shading; no specific composition.

WHITEWASH. A simple mixture of dry hydrated lime and water; some improved and more expensive whitewash powders contain opaque white pigments and additional binder, or are wholly of the calcimine or cold-water paint type. Common whitewash is not water-resistant, and rubs off easily.

Some Sources of Materials Mentioned in the Text

In a work of this nature it is difficult to recommend commercial brands or sources of materials; because of the ever-changing nature of trade conditions, one cannot vouch for the perpetuation of either the quality of any product or the policies of any firm.

These notes refer to basic raw materials, rather than to prepared or manufactured artists' materials, except in a few cases where outstanding, reliable products have been established.

The regular retail sources of chemicals and raw materials are to be recommended; when materials are unobtainable from them, some of the large manufacturers and direct importers will sell their products direct in lots of one gallon or one to five pounds; most of them, however, prefer not to do this, but will recommend retail sources.

The mention of a source for a raw material does not necessarily imply a blanket recommendation for everything offered for sale by the concern, especially where it handles prepared or manufactured painting supplies as well as basic raw materials.

Obvious difficulties prevent the list from being exhaustive, and it has been rather localized around London.

Complete but rather indiscriminate lists of manufacturers and dealers in miscellaneous chemicals and raw materials, covering Great Britain, may be consulted in the following two publications:

British Chemicals and Their Manufacturers, the official Directory of the Association of British Chemical Manufacturers, 166 Piccadilly, London, W. 1.

Where to Buy Everything Chemical, 'Where to Buy' Ltd., 49 Wellington Street, London, W.C. 2.

No distinction is made in these books between large-scale manufacturers, brokers, and establishments which sell small quantities at retail.

Several of the well-known manufacturers of prepared artists' painting materials sold at artists' supply stores put up simple materials such as damar and mastic varnishes, stand oil, and Venice turpentine, in small bottles; the convenience and availability of these small amounts are at least partial compensation for their higher cost. The painter who is experienced with these products can usually judge their quality.

The firms in the following lists are arranged in alphabetical order.

General Raw Materials and Chemicals

There are dealers in most large cities, especially in industrial centres, who sell small retail amounts of a general line of chemicals and raw materials in both technical and chemically pure grades. Some of them specialize in supplies for industrial manufacturers; others are also wholesale druggists. Although they will seldom disclose the original sources of the goods they offer for sale, these products can usually be relied upon; the business of such concerns depends upon supplying the correct material for the purpose. However, the grades of raw materials, especially of products such as oils and resins, which are adequate for industrial use, are often not the best possible for artists' use. These concerns will usually stock additional supplies if there is a reasonable demand for them, or they will secure special materials on order. The following are a few firms of this type:

Stafford Allen & Sons, Ltd., 20–42 Wharf Road, City Road, N. 1.
A. Boake, Roberts & Co., Ltd., 'Ellerslie,' Buckhurst Hill, Essex.
W. J. Bush & Co., Ltd., 28 Ash Grove, Hackney, E. 8.
Evans Medical Supplies Ltd., Speke, Liverpool, 19.
T. & H. Smith Ltd., Blandfield Chemical Works, Wheatfield Road, Edinburgh, 11.
Thomas Tyrer & Co., Ltd., Stirling Chemical Works, Stratford, E. 15.
General Chemical & Pharmaceutical Co., Ltd., Judex Works, Sudbury, Wembley, Middlesex.
Hopkin & Williams Ltd., 16–17 Cross Street, Hatton Garden, E.C. 1.

Laboratory Supplies and Apparatus

These are obtainable in most large cities; the following are some of the many suppliers:

Laboratory Equipment Co., 23 Sidmouth Mews, W.C. 1.

Scientific Glassblowing Co., Ltd., 95 Grays Inn Road, W.C. 1.
Scientific Supplies Co., Ltd., 15 Vine Hill, E.C. 1.

Among the simpler pieces of laboratory apparatus and equipment which are useful in the studio, are the following:

For grinding pigments and other dry materials, also grinding or mixing powders with liquids—a glass mortar and pestle; these are obtainable in various sizes. The porcelain varieties are preferred by some, but the glass ones are usually adequate and more easily cleaned.

For dividing mixed liquids which will separate into two layers (for instance, for separating the oil from water in the sun-refining process)—a separatory funnel, which is a globular container with a stopper on top and a long stem below; the flow of liquid is controlled by a stop cock at the point where the stem meets the globe. The funnel is held in a common ring or clamp stand while in use.

The suction pump, bottle, and Buchner funnel described on page 97.

Glass mullers, described in connection with the home manufacture of oil colours.

Other miscellaneous pieces of equipment whose value depends upon the type of work being done are the following, obtainable from common retail stores:

For the intimate mixing or blending of pigments and other dry powders —a rotary flour sifter.

Aluminium egg-separator.

Rotary egg-beater and jar.

Small household or beverage mixer with electric motor. The kind which can be held in the hand as well as set into a stand is most convenient. More expensive and more professional small mixers have motors designed for continuous operation. A mixer may also be improvised by attaching a small motor, such as one from an electric fan or a dictaphone, to a vertical propeller shaft.

One-ounce, screw-cap, clear glass jars to contain tempera paints, colours ground in water, etc. Larger sizes are also useful for storage of pigments.

Measuring equipment is mentioned on pages 419–20.

Solvents

Turpentine. The clean, fresh material known as 'gum turpentine', when purchased from a well-established paint store which buys its materials in standard grades from reputable manufacturers, is identical with the so-called double rectified turpentine put up in small bottles and sold by artists' supply dealers, and is likely to be fresher stock. The dealers in the artists' grade are certainly entitled to a higher price in return for their careful selection of pure material and for the investment required to carry it in stock in conveniently small bottles, but the pure turpentine sold in bulk is not inferior in quality. It should be rejected if it is cloudy, yellow, or if its odour is strange. If the head

of the barrel or the label on the can in which the dealer receives his shipments bears the name of the original producer and the words 'pure gum spirits of turpentine', this is a further guarantee, because such labelling and nomenclature are regulated by the government, as noted on page 265.

Mineral Spirit. This material may also be purchased at paint stores. It is usually called turpentine substitute or white spirit. It should be distinguished from the other common material sold as painters' benzine or naphtha.

Alcohol. The strength of alcohol (percentage of alcohol in relation to the percentage of water) is reckoned by the 'proof' system. In Britain, 99·24% or absolute anhydrous alcohol is 74 o.p. (over proof), 95·82% or Industrial water white is 68 o.p., 93·55% is 64 o.p. (The usual denatured alcohols available to the public are 61 and 64 over proof). The United States system is different. The sale of the specially denatured alcohols is strictly regulated by H.M. Customs and Excise; such materials are not sold at retail but only to industrial concerns. A permit to buy pure grain alcohol or anhydrous alcohol for stated purposes, especially in small amounts, can sometimes be obtained from the local Officer of H.M. Customs. His address can usually be obtained from the district post-office.

Other Solvents. All of the other solvents mentioned in this book can be purchased from the raw-material and chemical supply houses listed above, in the ordinary or technical grades as well as in the more expensive chemically pure grades. The best-quality technical grade of a solvent will often be found suitable for most studio uses, especially when a purer grade is very expensive; but usually, when the purest grade is obtainable, the difference in price will not make it worth while to use the inferior grades, particularly when only small quantities are needed. As a general rule the pure grades are more pleasant to handle because of their more agreeable odour.

Ethyl Silicate

This material can be obtained direct from Silicon (Organic) Developments Ltd., Victoria Station House, Victoria Street, London, S.W. 1 or from Silica Seal Ltd., Westgate Hill Grange, Newcastle-on-Tyne.

Varnish Resins

Among the many importers of gums and resins are:

Fletcher, Morgan & Co., Culmore Works, Clifton Crescent, S.E. 15.
M. Hamburger and Sons, Ceylon House, Eastcheap, E.C. 3.
Henry Miller & Co., Ltd., 60 Grange Road, Ealing, W. 5.
Watts Ltd., 72–75 Fenchurch Street, E.C. 3.

These dealers, although their trade is usually in large quantities, will sell as little as five pounds direct.

Synthetic Resins (Plastics)

All synthetic resins are marketed under trademarked names; these products and their sources are identified in the technical books on the subject. Those suitable for varnish use are made in heavy solution form as well as in the solid state. Few, if any, are available to non-industrial consumers in small lots.

Adhesives

Glues. The sheets of French rabbit-skin glue mentioned in the text bear the imprint 'Chardin, Pantin, France', and the material is obtainable from most of the retail dealers in technical raw materials and chemicals and from some of the more complete paint stores.

A pure rabbit-skin glue which appears to be about equal to the French product is made in powdered and sheet forms by the Union Glue and Gelatine Co., Ltd., Cransley Works, Garrett Street, Golden Lane, E.C. 1. Because of long usage and wider availability in retail amounts, the French material seems to be the standard. Calf-skin glues, paler, cleaner, and definitely stronger in jelly strength than rabbit-skin glue, are also available; recipes for employing them to replace rabbit-skin glue must be worked out by the user. They are closely related to gelatin, but their properties are balanced enough for general adhesive and binding purposes.

Gelatin. The best grades of clear, white technical gelatin are sold in powdered form; the imported varieties come in thin sheets put up in packages wrapped in blue paper. Gelatin is usually obtainable from the dealers in general chemicals and raw materials or from the Union Glue and Gelatine Co., Ltd., mentioned above.

Fish Glue is sold in liquid form, and may be purchased in hardware and chain stores in good quality in small bottles and tins.

Casein. Casein will not give good results unless it is fresh stock and of the best quality. It is normally obtainable from the usual general chemical or raw-material supply houses; but casein is now totally controlled by the Board of Trade, who are the sole importers and distributors. If the use for which it is required is approved supplies are drawn from The Lactic Casein Importers Association Ltd., 23 St. Swithin's Lane, E.C. 4.

The prepared casein adhesive is sold in powder form under trademarked names such as Casco Casein Glue, Certus, Lactocol, Laitzo XXX, etc. The first-mentioned firm produces a flexible adhesive, Casco Cement, which is the casein-latex cement referred to on page 249. These adhesives can be obtained in most ironmongers, domestic, and paint stores; instructions on the package must be carefully followed.

Pigments

Dry colours are sold in small amounts in some artists' supply stores; they are put up in small packages by some of the well-known manufacturers of prepared artists' materials.

A very complete supply of dry artists' pigments, sold in small amounts, will be found at L. Cornelissen & Son, 22 Great Queen Street, London, W.C. 2

While painters who use dry colours should insist upon securing the purest, highest-grade pigments, there are some purposes for which more commonplace and more easily obtainable grades are useful. These grades are universally sold in paint stores. For the best artistic painting purposes, however, only pigments of known origin should be chosen, and for these one should go to reliable dealers who have the knowledge and facilities to test and select their supplies from among the best sources.

All colours sold for ceramic uses are specially treated. They contain fluxing and refractory ingredients and are not suitable for paint purposes.

Containers

Percenta Ltd., 130–132 Tooley Street, London, S.E.1, carries an assortment of lever-lid paint tins and screw-top cans. Rawbridge Ltd., Dutch River Works, Rawcliffe, near Goole supply an assortment of bottles and cartons. Empty tin tubes, double 4 inch and ½ lb. size, can be obtained from J. Bryce Smith Ltd., 117 Hampstead Road, London, N.W. 1.

Gold and Other Metallic Leaf, Gold Size, Bronze Powders, and Accessories

These materials can be obtained from such Artists' Colourmen as J. Bryce Smith or Cornelissen, addresses as above, or from some oil and colour merchants. Gold leaf in Britain is in extremely short supply; retailers now receive only a small quota at infrequent and irregular intervals.

Oils

Selected painting oils are put up in small bottles by the manufacturers of prepared artists' materials; when it is important to use the best grades of exact materials, only the very highest-quality brands are reliable. When larger amounts are required, when one desires more exact identification of the oil, or when for the sake of economy one is willing to take the trouble of shopping for and storing a large can of oil, these materials may be purchased in lots of one gallon or more from the general raw-material supply houses.

The varieties of industrial linseed oil mentioned in the text, paint grinding oil, bleached paint grinding oil, varnish oil and stand oil are widely manufactured, the following manufacturers are among many:

Biddle, Sawer & Co., Ltd., 4 Grafton Street, London, W. 1.
William Butler & Co., Ltd., St. Philips, Bristol 2.
Dussek Brothers & Co., Ltd., Thames Road, Crayford, Kent.
John M. Hamilton & Co., Ltd., Humber Oil Works, Hull.

They are not sold direct to retail users, but may sometimes be obtained

through the retail dealers in general raw materials. The price range of the various kinds of linseed oil is not great; while the costs fluctuate according to market conditions, there is seldom a differential of more than a few pence per gallon between linseed oils of various degrees of refinement. The fact that an oil is unsuitable for artists' use does not necessarily signify that it is an inferior oil; all these oils are made with equal care to meet the requirements of their various purposes.

As noted in the text, the highly bleached paint oils are less desirable than those of a more normal colour, but the colour stability of stand oil, and perhaps some of the modern pale varnish oils, is satisfactory.

Poppy and Walnut Oils. These are retailed by the manufacturers of artist's oils and colours and can usually be obtained from an artists' supply stores; they can be obtained through the trade, in larger quantities, only under licence from the Board of Trade.

Dyes

Dyestuffs for all purposes, soluble in water, oil, or alcohol, may be purchased from:

Cole & Wilson Ltd., 24 Greenhead Road, Huddersfield.
Colne Vale Dye & Chemical Co., Ltd., Milnsbridge, Huddersfield.
Garthwood Co., Ltd., 4 Lloyds Avenue, London, E.C. 3.
Imperial Chemical Industries Ltd., Nobel house, 2 Buckingham Gate, London, S.W. 1.
A. E. Robinson & Co., Wesley Road, Leeds, 12.
The Yorkshire Dyeware & Chemical Co., Ltd., 24 Lower Basinghall Street, Leeds, 1.

White Lead in Oil

For priming canvases and for other uses which will consume comparatively large quantities of paint and which do not warrant the purchase of the expensive and more carefully prepared flake and Cremnitz whites sold as artists' tube colours, white lead ground in oil may be bought in tins or pails. The brands of the large well-established producers are carefully compounded and serve well for these purposes. Most of them are blends of pure white lead carbonates made by more than one process.

The modern product is now sold in two varieties, one is straight white lead in oil, the other is a softer paste which contains a small amount of turpentine or mineral spirit so that it can be more easily broken up with oil and thinners and mixed with tinting colours.

Some of the widely distributed brands are made by:

British Chemical Products & Colours Ltd., 6–7 Buckingham Street, W.C. 2.
Lonabarc Ltd., Cranbrook Road, Ilford, Essex.
Metallo Chemical Refining Co., Ltd., Palmerston House, Bishopsgate, E.C. 2.
The Mersey White Lead Co., Ltd., Warrington, Lancashire.

Other Pigments in Oil

Zinc oxide and all the common pigment colours sold in tins at paint stores are ground in oil to a rather soft consistency. They are useful for some purposes, but never as oil colours for artistic painting. They should bear the label of a well-known, reputable maker, and the zinc oxide should be of the French process variety (red, green, or white seal). The best brands of zinc are ground stiffer than the other tinting colours and are useful in making oil grounds, etc. The cheap grades of painters' colours in oil sold in tins are often poorly ground and grossly adulterated. The coloured pigments are ground with an excess of oil for convenience in tinting liquid paints and, even if pure, are poorly adapted to most techniques of artistic painting.

Glass Mullers

Mullers may be had from various artists' supply stores or from general chemical and laboratory supply houses.

Porcelain Enamelling

The following concerns are experienced in firing the finished work:
Defiant Enamel Co., Ltd., John Penn Street, London, S.E. 13.
Vitreous Enamelling Works, Osborne Road, Acton, London, W. 3.

Ceramic colours, may be purchased from Martin Colour Co., Ltd., Gate Street Mills, Hanley, Staffs., and from Alec. Tiranti Ltd., 72 Charlotte Street, London, W. 1.

Washable Casein Wall Paints

Under a great variety of trademarked names, such as Arduro, Beldec or Duresco, these paste or semi-liquid paints are sold in most paint stores. A gallon will make about 1½ gallons of finished paint. Some dry-powder paints are sold in competition with them; these are seldom of equal value, and will not usually produce as fine or resistant a surface.

Industrial Paints, Etc.

In buying ready-mixed paints, enamels, varnishes, lacquers, etc., one should select the products of the large, nationally known, reputable companies; materials which are not sold below the generally prevalent prices for highest-quality goods are usually guaranteed against inferior results. The majority of failures of such materials are caused by improper selection of the product for the purpose, or by improper application. Well-established, complete retail stores are usually able to supply information and advice on these prepared products.

Lithographers' Supplies

Crayons, transfer paper, tusche, etc., are obtainable at some artists' supply stores. The following are dealers in complete equipment and supplies for lithographers, both artistic and industrial:

L. Cornelissen & Son, 22 Great Queen Street, London, W.C. 2.
Hunter-Penrose Ltd., 109 Farringdon Road, London, E.C. 1.
W. C. Kimber, Tankerton St. Works, Cromer Street, London, W.C. 1.

Etchers' and Engravers' Supplies

A well-stocked artists' supply shop will often carry enough etchers' and engravers' materials for most purposes; the following concerns specialize in these materials and are listed under their main specialities:

Etchers' and engravers' supplies, tools, copper and zinc plates, steel facing of etched plates:

W. C. Kimber, Tankerton St. Works, Cromer Street, London, W.C. 1.
W. Y. Rhind, 69 Gloucester Road, Regents Park, London, N.W. 1.

Wood blocks for engraving and cutting can also be obtained from the above firms, or from T. N. Lawrence, 4 Red Lion Court, Fleet Street, London, E.C. 4, who specializes in wood engraving tools and materials.

Sculptors' Materials

A complete range of tools for wood and stone carving, modelling and plaster casting is supplied by Alec. Tiranti Ltd., 72 Charlotte Street, London, W. 1. There are no specific suppliers of woods for carving, Tiranti can sometimes supply small pieces but a general timber yard is the common source. Likewise, there are no specific suppliers of marbles and other cut stones for private sculptors; small supplies can sometimes be obtained from firms of monumental masons but the quarry itself is the usual source. The Directory of Quarries and Clayworks etc., published by The Institute of Quarrying, Salisbury Square House, London, E.C. 4 contains a comprehensive catalogue of British quarries and the stones and materials they can supply.

Plastic Magnesia, Fillers and Supplies.

Names of suppliers of plastic magnesia can be obtained from The Jointless Flooring (Oxychloride) Association, 69 Cannon Street, London, E.C. 4.

Commercial Standard for Artists' Oil Paints

The following are the specifications to which reference is made on pages 23 and 309. After being approved by manufacturers and by artists' organizations according to the procedure of the American National Bureau of Standards, they were officially promulgated and went into effect May 10th, 1942.

A standing committee upon which manufacturers and artists' organizations are equally represented will arrange for future improvements and

periodic revisions, and it is expected that, if the project is successful, standards governing minimum quality requirements will be adopted for all other artists' supplies that can be so regulated. The material and data upon which this project was based were developed by the Paint Testing and Research Laboratory of the Massachusetts WPA under the direction of Frank W. Sterner and Rutherford J. Gettens.

Printed copies of Commercial Standard CS 98–42, Artists' oil paints, may be purchased from the Superintendent of Documents, Washington, D.C., at 5 cents each.

Recommended Commercial Standard for Artists' Oil Paints

As adopted by the General Conference held in New York, February 9, 1940, with subsequent adjustments by a special committee appointed by the General Conference.

PURPOSE

1. The purposes of the commercial standard are to serve as a guide to artists in the purchase of paints of satisfactory colour, working quality, and durability; to eliminate confusion in nomenclature; to promote fair competition among manufacturers by providing criteria for differentiation among paints of known satisfactory composition and others of unknown or inferior quality and thus to provide a basis for certification of quality.

This commercial standard covers minimum requirements for artists' oil paints of satisfactory colour and durability. It is not intended that all paints meeting the requirements shall be identical, nor of uniform excellence in all respects. Variations in manufacture and grinding not controlled by the specification may cause some artists to prefer one brand over another, both of which are acceptable under this specification.

SCOPE

2. This commercial standard covers one grade of artists' oil paints and includes criteria of colour, nomenclature, chemical composition, working qualities, lightfastness and performance. It also covers methods of testing to demonstrate conformance with the standard, packaging, and certification of quality.

NOMENCLATURE

3. The paint names given in Table 1 and Table 2 indicate the chemical nature of the pigment or are those which, through usage, have become associated with that pigment. The use of these names for similarly coloured pigments is not permitted by this standard.

GENERAL REQUIREMENTS

4. *Pigments* shall be of good grade. Composition and identity shall conform to Table 1 and Table 2. Organic lakes or toners shall not be used to fortify or sophisti-

cate inorganic pigments. Substitution of similarly coloured pigments is not permitted.

5. *Vehicles* shall consist of pure drying oils, linseed and/or poppy oil only.

6. *Driers* may be used in minimum amounts in paints that contain pigments which have a retarding effect on the drying of oils to allow them to conform to drying-rate requirements (paragraph 7). The maximum amount of drier, however, shall not exceed 0·2 per cent cobalt or 0·1 per cent manganese, calculated as metal, on the weight of oil.

7. *Drying rate* shall be determined by the sand and pressure testing devices. Paints shall dry to both tests within 21 days and not under 3 days at 76° F. and 55 per cent relative humidity. See paragraph 18.

8. *Consistency* of artists' oil paints shall be determined by use of a standard 2-kilogram Paste Paint Consistometer. Readings between 2 and 5 will be acceptable under this standard. See paragraph 20.

9. *Brushing* quality of artists' oil paints shall be determined by observing the handling quality of the paint when manipulated with a brush. All artists' oil paints shall brush out smoothly, evenly, and easily, leaving a normal brush mark. They shall not be sticky, thick, or rubbery, nor too fluid. There shall be no free or excess oil. They shall not contain skin and shall be uniformly ground. They shall retain their form and shall not level out when applied with a palette knife. See paragraph 21.

10. *Tinting strength* of artists' oil paint shall not be less than that of the standard adopted for each pigment. See paragraph 22.

11. *Composition* of the paint, governed by the relative amounts of vehicle, pigment, and inert used, shall produce a paint of satisfactory working qualities, conforming to all requirements of this commercial standard.

12. Inerts and fillers shall not be used in amounts that will impair the tinting strength, the drying time, and the working qualities of the paint.

13. Metallic soaps and/or refined beeswax may be used in minimum amounts to produce desirable working qualities, consistency, and to prevent settling of pigment, but the quantity used shall not exceed 2 per cent of the weight of the pigment.

DETAIL REQUIREMENTS

14. *Light-fastness.* All pigments included in Tables 1 and 2 have been shown to resist fading satisfactorily when used in oil painting and under normal conditions of exposure. No accelerated method of testing for light-fastness has been found to be directly comparable with normal use conditions, but, for purposes of test, exposure to sunlight under specified conditions has been found to be of some value as a means of grouping paints on the basis of fastness under test conditions. The grouping of pigments covered by this commercial standard, when painted in oil on non-absorbent supports and unmixed with other pigments, is shown in Tables 1 and 2.

14a. Group I paints shall resist fading to direct sunlight at southern exposure under glass at 45° angle for 2 months. This shall include at least 600 hours' sunlight, as shown by weather reports from the nearest United States Weather Bureau Station.

14b. Group II paints shall resist fading to direct sunlight under above conditions for 1 month. This shall include at least 300 hours' sunlight.

14c. The above tests shall be made in the period from April 1 to October 1 of any

given year. If this method is impracticable, or in case of dispute, the paints shall be tested under conditions agreed upon by all parties concerned.

15. *Names* under which artists' oil paints conforming to this commercial standard are sold, the pigments used in their composition, and the light-fastness group of each, shall conform to Table 1 and Table 2, Glossary of Terms. Only paints whose labels and contents conform to the nomenclature and composition as indicated in the Glossary of Terms are acceptable. To assist in transition from past nomenclature to the standard nomenclature as employed in the Glossary of Terms (Tables 1 and 2), the manufacturer shall be permitted for a period of two years after acceptance of this standard to carry on the label as a subtitle, in smaller type and in parentheses, his customary designation for pigment identity or colour description with which his clientele has become accustomed, but use of such subtitles shall be discontinued at termination of the two-year period.

TABLE I. STANDARD PAINTS—GLOSSARY OF TERMS

Paint Name	*Pigment*	*Test Group (cf. par. 14)*
Alizarin crimson	The synthetic or natural red organic dyestuff 1, 2-dihydroxyanthraquinone precipitated on a base of aluminium hydrate	Group I
Alizarin rose madder	The synthetic or natural red organic dyestuff 1, 2-dihydroxyanthraquinone precipitated on a base of aluminium hydrate	Group I
Burnt sienna	Iron oxide prepared by calcining the natural earth, raw sienna	Group I
Burnt umber	Iron oxide and manganese dioxide pigment prepared by calcining raw umber	Group I
Cadmium orange	Cadmium sulphide, CdS or cadmium sulphoselenide, CdS + CdSe	Group I
Cadmium red deep Cadmium red medium Cadmium red light	Cadmium sulpho-selenide, CdS + CdSe	Group I
Cadmium-barium red deep Cadmium-barium red medium Cadmium-barium red light	Cadmium sulpho-selenide coprecipitated with barium sulphate, CdS + CdSe + $BaSo_4$	Group I
Cadmium yellow deep Cadmium yellow medium Cadmium yellow light	Cadmium sulphide, CdS	Group I

Paint Name	*Pigment*	*Test Group (cf. par. 14)*
Cadmium-barium yellow deep Cadmium-barium yellow medium Cadmium-barium yellow light	Cadmium sulphide coprecipitated with barium sulphate, $CdS + BaSO_4$	Group I
Cerulean blue	Combined oxides of cobalt and tin, CoC. $nSnO_2$	Group I
Chromium oxide green	Anhydrous chromic oxide, Cr_2O_3	Group I
Cobalt blue	Combined oxides of cobalt and aluminium, $CoO.Al_2O_3$	Group I
Flake white	Basic lead carbonate, $2PbCO_3.Pb(OH)_2$	Group I
Green earth	Natural earth consisting chiefly of the hydrous silicates of iron, aluminium, magnesium, and potassium	Group I
Indian red	Nearly pure iron oxide Fe_2O_3. It may be either natural or artificial in origin.	Group I
Ivory black	Amorphous carbon produced by charring animal bones	Group I
Lamp black	A nearly pure amorphous form of carbon made from the condensed smoke of a luminous flame	Group I
Light red	A natural iron oxide, Fe_2O_3, with varying proportions of inert	Group I
Mars orange	Artificial ochre consisting chiefly of iron and aluminium oxides, $Fe_2O_3 + Al_2O_3$	Group I
Mars red	Artificial ochre consisting chiefly of iron and aluminium oxides, $Fe_2O_3 + Al_2O_3$	Group I
Mars violet	Artificial iron oxide, Fe_2O_3	Group I
Mars yellow	Artificial ochre consisting chiefly of hydrous oxide of iron and aluminium, $Fe_2O_3.nH_2O + Al_2O_3.nH_2O$	Group I
Phthalocyanine blue	A synthetic organic dyestuff which is copper phthalocyanine	Group I
Phthalocyanine green	Synthetic organic dyestuff which is chlorinated copper phthalocyanine	Group I
Raw sienna	Natural earth that consists chiefly of the hydrous silicates and oxides of iron and aluminium	Group I
Raw umber	Natural earth that consists chiefly of the hydrous oxides and silicates of iron and manganese	Group I
Titanium white	A white containing at least 30% titanium dioxide (TiO_2) and free from lead; balance either $BaSO_4$ and/or ZnO	Group I

Paint Name	*Pigment*	*Test Group (cf. par. 14)*
Ultramarine blue	Complex silicate of sodium and aluminium with sulphur	Group I
Ultramarine red	Complex silicate of sodium and aluminium with sulphur	Group I
Venetian red	Artificial or natural iron oxide, with varying proportions of inert	Group I
Viridian	Hydrous chromic oxide, $Cr_2O_3.2H_2O$	Group I
Yellow ochre	Artificial or natural mixture of hydrous iron oxide with alumina and silica	Group I
Zinc white	Zinc oxide, ZnO	Group I

Note: There is no claim that all the pigments listed above are stable and desirable under all conditions. The list at present includes only the better-known and more stable pigments. It is to be understood that the chemical formulas used in the tables are not intended to indicate the exact chemical composition of the pigments but rather their approximate or substantial composition. It is recognized that in the preparation of certain pigments it is often necessary to incorporate modifying materials which are not to be regarded as fillers, extenders, or adulterants.

16. *Special paints* listed under Table 2 include those which may not be regularly supplied by some manufacturers because of little demand, but are listed in this standard for those who wish to purchase them.

TABLE 2. SPECIAL PAINTS—GLOSSARY OF TERMS

Paint Name	*Pigment*	*Test Group*
Cobalt green	Combined oxides of zinc and cobalt CoO. *n*ZnO	Group I
Cobalt violet	Anhydrous cobalt phosphate, $Co_3(PO_4)_2$, or arsenate, $Co_3(AsO_4)_2$	Group I
Cobalt yellow	Potassium cobaltinitrite, $CoK_3(NO_2)_6.H_2O$	Group II
Manganese blue	Barium manganate with barium sulphate, $BaMnO_4 + BaSO_4$	Group I
Manganese violet	Manganese ammonium phosphate, $MnNH_4PO_4$	Group I
Prussian blue	Ferric ferrocyanide, $Fe_4(Fe(CN)_6)_3$	Group I
Strontium yellow (Lemon yellow)	Strontium chromate, $SrCrO_4$	Group II
Ultramarine green	Complex silicate of sodium and aluminium with sulphur	Group II
Van Dyke brown	Bituminous earth or lignite, with small amounts of iron, alumina, and silica	Group II
Vermilion	Mercuric sulphide, HgS. Can be designated as English, French, or Chinese	Group II
Zinc yellow	Zinc chromate, $ZnCrO_4$	Group II

METHODS OF TEST

17. *Pigments* generally may be identified by the usual methods of analysis and identification of inorganic and organic compounds. In cases of doubt the methods employed by the Massachusetts Art Program, Paint Testing and Research Laboratory, may be used.

18. *Drying rate:* Preparation of samples, apparatus, and schedule given below.

18a. *Apparatus:*

1. Humidity- and temperature-controlled test room, maintaining approximately 76° F. temperature and 55 per cent relative humidity.
2. Sand testing apparatus.
3. Pressure testing apparatus.
4. Bronze template 0·010″ thickness for use on 3 × 5″ test panels. (See below.)
5. 3 × 5″ glass panels (window glass thickness).
6. 2 ml. capacity measuring ring.
7. Doctor blade.
8. 50 ml. burette.
9. Palette knife.
10. Glass or marble mixing slab.

18b. *Preparation of test panels:* Two ml. of the paste paint are measured out in the ring and placed on the test plate; ½ ml. of turpentine is added and thoroughly mixed with the paste with a palette knife. The thinned paint is spread out on the glass panel to 0·010″ thickness with the aid of the template and a doctor blade.

18c. *Schedule:* All tests are to be conducted in the controlled test room and the specimens are to remain there until the tests are completed. The first test is to be made at the end of 3 days (72 hours) and the second at the end of 21 days (504 hours) after the paint has been applied and the sample has been deposited in the test room.

18d. *Procedure and interpretation:*

18d 1. Surface drying rates shall be tested with the sand type instrument,* which permits one gram of sand to flow over the painted surface held at an angle 45° with the vertical. For incidental tests, if this instrument is not available, sand may be poured by hand from a teaspoon. Sand shall not stick to the film nor leave a visible mark.

18d 2. Film drying rate shall be tested with the pressure type instrument,* by which two hundred grams weight is applied. For incidental tests, an ordinary metal ring with a sharp edge (like a wedding ring) pressed on the paint film by a 200 gram weight may be used. The ring shall leave no visible mark on the film.

19. *Light-fastness* shall be determined in an out-of-door (roof) exposure rack which is constructed to hold panels at a 45° angle to south exposure. The specimen shall be protected from rain and dirt by glass windows placed not less than two inches from the surface of the specimen. The windows shall be kept clean throughout the test. No obstruction shall interfere with exposure to full sunlight at all times of the day.

19a. *Support for exposure tests* shall be smooth opaque white, or opal, glass. Two specimen panels at least 3 × 5 inches in size shall be prepared by brushing out the paint as it comes from the tube without addition of thinner. In referee tests a Bird

* For photograph and description, see ninth edition of Gardner's book,[14] pp. 110–1.

applicator giving a film thickness of 0·003 inch shall be used. When dry, but not before one week, one specimen is placed in the exposure rack and left for a period conforming to its test group (see paragraph 14). The control panel shall be kept in diffused light during the period. The extent of fading shall be judged by comparison of the exposed panel with the control panel. A suitable varnish may be applied to differentiate between fading and chalking.

20. *Consistency* is measured with an instrument by which the paste paint is deformed under pressure.

20a. *Equipment:*

1. Brass template approximately 4 inches square and 0·250 inch thick with centred hole holding 2·0 ml. of paint. (Diameter 0·79 inch.)
2. Glass plate with concentric circles, numbered from 1 to 7, and spaced 1 cm., 2 cm., 3 cm., 4 cm., 5 cm., 6 cm., and 7 cm. from the inner circle whose diameter corresponds to the centred hole in the brass template. The chart is drawn on paper and glued to the back of the glass.
3. Wooden frame for housing template and glass.
4. Palette knife for applying paint to template.
5. Two-kilogram weight.
6. Glass plate for placing on top of paint after template has been removed.

20b. *Procedure:* Place the glass plate with concentric rings face up in the bottom of the wooden frame. Place brass template over glass plate; if no frame or housing is used be sure the template is centred. Fill hole of template with paint to be tested and level off. Lift template from plate, take the plain glass plate and lay on the paint and apply evenly the two-kilogram weight. Leave until the paint has ceased to spread. Paint of proper consistency shall spread over the No. 2 ring and not over the No. 5 ring.

21. *Brushing quality:* This test shall be performed by a technician skilled in the use of artists' oil paints. Settlement of dispute shall be referred to a committee of 3 technicians satisfactory to both parties. The technician should observe how the paint brushes out and handles, and he shall describe these qualities in the following terms:

(a) *Smooth*, describes a paint which spreads evenly and easily, leaving a normal brush mark.

(b) *Sticky or tacky*, describes a paint which is thick, viscous, or rubbery and difficult to apply.

(c) *Fluid*, describes a paint which flows too rapidly for correct handling. Paints very fluid in character leave little or no brush mark, and when applied in impasto lose form and 'level out'. Any change in the levelling of paint over a period of 24 hours should be observed.

22. *Tinting strength:*

22a. *Equipment:*

(1) Template, measuring ring, or other suitable device for volumetric reduction of paste paints, 20:1 and 10:1.
(2) Pieces of flat glass for use in mixing the paste.
(3) Flexible spatula having a 3-inch blade for mixing.
(4) Scraper or flexible doctor blade for smoothing down the paste colour for comparative purposes.
(5) Standard tint for the paint to be tested.

Note: A limited number of sets of standard tints of all paints listed in Tables 1

and 2 are available, under appropriate conditions, to those who are required to compare manufactured paints with the standards, by applying to the Chairman of the Standing Committee for this standard. These standards are made in volumetric ratios of 20:1 and 10:1 with the zinc oxide standard reduction paste described in section 22b.

b. *Materials:*

(1) Zinc oxide standard reduction paste made from the following formula as outlined by the Federation of Paint and Varnish Production Clubs, Official Digest, No. 120, 1029 (November, 1932), and published in H. A. Gardner's *Physical and Chemical Examination of Paints, Varnishes, Lacquers and Colours*, 9th edition, 1939, p. 33.

300 parts by weight Green Seal zinc oxide
64 parts by weight poppy seed oil
2 parts by weight calcium stearate
1 part by weight turpentine

c. *Procedure:*

(1) Reduce one volume of the paint to be tested with 20 volumes of the standard reduction paste. Mix thoroughly with spatula on glass plate. Paint out the reduced paint on a suitable support and, after drying, compare the colour strength with the tinting strength standard for the pigment being tested. Regard strength (value) only; differences in colour caused by naturally occurring differences in pigments shall be disregarded. The colour tinting strength shall equal or exceed the standard. (The tinting strength tests for green earth and ultramarine blue [Table 1] and cobalt violet [Table 2] are made by reduction with standard reduction paste 10:1. The tinting strength standards of paints made with these pigments have been made by 10:1 reduction [instead of 20:1] because they have inherently low tinting strength.)

LABELLING AND PACKAGING

23. *Packaging:* Artists' oil paints shall be packaged in tubes made of suitable metal.

a. Standard size tubes shall be approximately 1 by 4 inches over-all and shall contain not less than 37 ml. of paint.

b. When smaller size tubes are required, they shall be approximately ½ by 4 inches over-all, containing not less than 10 ml., or approximately ½ by 2 inches over-all, containing not less than 5 ml.

c. White paint may be packaged in tubes approximately 1½ by 6 inches over-all containing not less than 150 ml.

24. *Labelling* of artists' oil paints shall indicate the following:

a. The complete paint name indicating pigment composition in conformance with the standard nomenclature in the Glossary of Terms, Tables 1 and 2, sections 15 and 16, shall be clearly printed on one side of the tube in letters of equal size and importance, Subtitles, which are permitted for two years (see paragraph 15), shall appear in smaller type and in parentheses directly under the paint name.

b. Contents expressed in millilitres.

c. The certification of conformance to the commercial standard.

CERTIFICATION

25. It is recommended that artists' oil paints conforming to this commercial standard shall be certified by the manufacturer through the use of the following statement appearing on labels or invoices:

'The ——— Company certifies this artists' oil paint to conform to all requirements of Commercial Standard CS 98–42, issued by the National Bureau of Standards.'

Bibliographies

In the following lists of books,* an attempt has been made to select representative works on each subject, rather than to collect every available reference. The lists are therefore by no means exhaustive. As far as possible they include only widely available volumes; few of the books mentioned are not to be obtained at the larger, more complete libraries. An effort has also been made to limit the listings to English and American works, mention being made of books in other languages only when they contain significant material not available in English. Most of the complete manuals and studies listed contain extensive bibliographies on their specialized subjects; these should be consulted when further titles are required.

The annotations are intended as brief guides. Partly adverse criticism does not imply that the work is considered bad; books of slight value and outmoded books have been excluded. Inclusion not only denotes approval, at least in part, but in many cases indicates that the work has in some way influenced the material in this book. The lists of modern books are arranged in chronological order.

It may be remarked that few intelligent users of technical books expect that they can be taught a craft by reading about it; they recognize that such books are similar in function to their other means of acquiring proficiency, and that some degree of skill is required to get the best from them. Also there are valuable books on techniques which were written by artists on the basis of personal experience; these are naturally coloured by the writers' own artistic aims and practices, which are often at variance with those of the reader. One must be able to extract from such accounts the matter which is directly applicable to general technical procedure or to one's own purposes, and to overlook such prejudices and opinions as may be antagonistic to one's own. Technical works which have been written from an industrial or other non-artistic viewpoint are also difficult to apply, and only the artist of considerable practical experience in the materials or methods under discussion can adapt or transpose such matter to his own purposes. However, because this branch of the subject has a fundamental bearing upon any complete study of the materials, selections of these works have been included.

Each of the following three general art bibliographies was compiled to be a guide for establishing the nucleus of an extensive and inclusive art library, the first being the most limited, since cost, availability, and, to some extent, language, were taken into consideration in its compilation.

List of books for a college art library—E. Louise Lucas. *The Art Bulletin*, Vol. XI, No. 3. New York, September, 1929.

Books on art, a foundation list—E. Louise Lucas. Cambridge, Fogg Museum of Art, Harvard University, 1936. A selection for the nucleus of a complete fine-arts library, including the most valuable and widely referred-to volumes, chosen without regard to availability, price, or language.

Suggestions for the library of a small museum of art—Lucy D. Tuckerman. Publications of the American Association of Museums, New series, No. 6. Washington, 1928. A list based on the library of the Worcester Art Museum.

* The Publishers listed are British firms unless otherwise stated.

Early Painting Materials and Methods

The older books, including those of the mid-nineteenth century which contain translations and comments based primarily upon studies of the early manuscripts, are valuable sources for study but as a rule cannot be used as practical manuals for artists. For example, the English books of the middle of the nineteenth century which mention tempera methods and materials were written from an oil-painting viewpoint, the interest in tempera being purely academic; the identification of raw materials mentioned in early documents and the interpretation of procedures recorded call for technical and artistic qualifications which the authors of these books did not always possess. See the next group of books for works written from a more modern viewpoint. Modern students apply analytical and synthetic methods to the examination of early works of art, and combine the results so obtained with the study of early writings to a greater extent than did former authors, the majority of whom relied almost entirely upon their own translations or interpretations of books and manuscripts.

1. *Theophrastus' history of stones*, with an English version and notes by Sir John Hill. London, C. Davis, 1774. Manuscript of the fourth century B.C.; one of the earliest Greek sources. Pliny incorporated it in his works. Mentions a few pigments, etc.

2. *Vitruvius on architecture*, edited and translated with notes by Frank Granger. William Heinemann, Ltd. A first-century B.C. treatise on architecture, building, and general mechanical and technical subjects, including many topics relating to the Roman materials and methods of fresco painting of the day, which were based on older practice.

3. *The elder Pliny's chapters on chemical subjects*, edited with translation and notes by Kenneth C. Baily. 2 Vols. New York, Longmans, Green, and Company, 1929.

4. *The elder Pliny's chapters on the history of art*, translated by E. K. Jex-Blake, with commentary and historical introduction by E. Sellers and additional notes by Dr. Heinrich Ludwig Uhrlichs. Macmillan & Co., Ltd., 1896. Pliny's work is largely a compilation of the general knowledge of his day (first century). Some of the details are based upon legend and hearsay, others are in complete accordance with established ideas and methods. Some of his material on painting comes from Greek sources, other parts stem directly from Vitruvius. He is rather vague on many important details of studio practice, either because he felt that they were common knowledge and not worth going into, or because he had slight first-hand acquaintance with them. Pliny, Vitruvius, and Theophrastus are almost our only literary sources for studies of Greek and Roman materials and techniques. When other writers of this and earlier periods are cited, it is usually with reference to a brief mention or to isolated remarks, sometimes merely a clue or the incidental use of a term or name of a material in some non-technical work.

5. *The Greek Herbal of Dioscorides*. 'Illustrated by a Byzantine A.D. 512, put into English by John Goodyear A.D. 1655, Edited and first printed by Robert T. Gunther, Oxford; printed by John Johnson for the author at the University Press, 1934.' Manuscript originally written in the first century, and rather widely disseminated and translated in medieval times. A description of natural products and some processes, written from a medical viewpoint. Mentions a few pigments, oils, resins, gums, and solvents.

6. *An Essay upon various arts by Theophilus Presbyter also called Rugerus*,

forming an encyclopedia of Christian art of the eleventh century. Original Latin with English translation by Robert Hendrie. John Murray, 1847. The treatise of Theophilus is generally accepted as the standard work on early Northern methods and materials, as that of Cennini is for Italy. The date is disputed, but is more often said to be twelfth than eleventh century. The work covers a variety of arts and crafts. There are also numerous earlier English and later French and German translations.

7. *Translations of Cennini*. This work was written in the fifteenth century and supplies our most authentic and complete description of early Italian painting techniques and materials. Three known manuscript copies exist; these have been studied and translated into English as follows:

Cennino de drea Cennini, written 1437 and published in Italian 1821 by Tambroni—Mary P. Merrifield. London, E. Lumley, 1844. The first English translation; of considerable interest, but superseded since 1899 by that of Lady Herringham.

The book of the art of Cennino Cennini—Christiana J. Herringham. Allen and Unwin Ltd., 1930. A carefully studied translation from the point of view of an artist and practical student of techniques, with notes including a review of and some comparisons with other early manuscripts, interpretations and explanations of the texts, and studies of the materials mentioned. Opinions on modern materials and their applications somewhat out of date (original edition 1899).

Cennino di Drea Cennini da Colle di Val d'Elsa. Il libro dell'Arte, edited by Daniel V. Thompson, Oxford University Press, 1932. The translation is in a companion volume:

The craftsman's handbook—Daniel V. Thompson, Oxford University Press, 1932. This presentation of the original and its translation are made in the light of modern understanding of the technology of painting.

8. *Vasari on technique*, translated by Louisa S. MacLehose. J. M. Dent Ltd., 1907. An English translation of a sixteenth-century book dealing with Italian Renaissance methods of sculpture, architecture, painting, and other arts and crafts, by the author of the well-known *Lives of the painters*.

9. *A critical essay on oil painting*—Rudolph Erich Raspe. London, H. Goldney, 1781. 'An essay on oil painting; proving that the art of painting in oil was known before the pretended discovery of J. and H. Van Eyck, to which are added Theophilus, de arte pingendi, Eraclius de artibus Romanorum etc., review of Farinator's Lumen Animae.'

10. *The art of painting in oil and in fresco*—J. F. L. Mérimée. Translated from the 1830 edition (Paris) by W. B. S. Taylor. London, Whittaker and Company, 1839. One of the first of the carefully written books on methods and materials; an authentic account of the knowledge of its day.

11. *A manual of fresco and encaustic painting*—W. B. Sarsfield Taylor. London, Chapman and Hall, 1843. One of the earliest complete and intelligent English studies on fresco.

12. *The art of fesco painting as practised by the old Italian and Spanish masters —with an inquiry into the nature of the colours used*—Mary P. Merrifield. London, C. Gilpin, 1846.

13. *Original treatises dating from the twelfth to the eighteenth centuries, on* the *arts of painting, etc., etc.* 2 Vols.—Mary P. Merrifield. London, John Murray, 1849. These two books contain translations of most of the well-known European manuscripts on painting techniques.

14. *Materials for a history of oil painting*—Sir Charles L. Eastlake. London, Longman, Brown, Green and Longman, 1847. One of the most complete studies of painting materials, methods, and techniques ever undertaken on the basis of literary sources of the past. There is also a two-volume edition of 1869, which contains added posthumous notes and an index which is lacking in the original; the author had planned to expand his work to larger proportions.

15. *Ancient and modern colours from the earliest periods to the present time with their chemical and artistical properties*—William Linton. London, Longman, 1852. A study of ancient colours and mediums from documentary sources.

16. *Hints to young painters and the process of portrait painting*—Thomas Sully. Philadelphia. J. M. Stoddart, 1873. Contemporary accounts of various early nineteenth-century American artists' techniques.

NOTE. Numerous practical handbooks on artists' methods and materials were written in England during the seventeenth and eighteenth centuries; they are interesting, but they seldom contain valuable information that is not found in the earlier works or matter of practical value that has not been superseded by nineteenth-century books. Most art libraries contain examples; a good list has been compiled by Laurie.[23]

MODERN STUDIES OF EARLY PAINTING MATERIALS AND METHODS

The general books on painting materials and methods listed in the next group contain many references to this subject, especially in relation to modern practice.

17. *Beiträge zur Entwickelungs-Geschichte der Maltechnik.* 5 vols.—Ernst Berger. Munich, Callway, 1904–09. Complete studies of painting techniques from manuscripts, archaeological relics, and chemical research. Fully illustrated. Contains some original opinions which have since been much disputed.

18. *Arts and crafts of ancient Egypt*—W. Flinders Petrie. Edinburgh, T. Foulis, 1909. Petrie has written much else on Egyptian techniques.

19. *Greek and Roman methods of painting*—A. P. Laurie. Cambridge, University Press, 1910. 'Some comments on the statements made by Pliny and Vitruvius about wall and panel painting.' Original interpretations and studies of early methods and materials.

20. *Fresco painting, its art and technique*—James Ward. Chapman and Hall Ltd., 1909. A description of the buon fresco process of Renaissance Italy and its adaptation to English practice; description of nineteenth-century English methods; critical studies of frescoes of the Italian masters.

21. The work of Noël Heaton on the Minoan frescoes, referred to in the text, was published in several papers, with additions and alterations appropriate to the interests of the various audiences to whom it was presented, as follows: 'The decorator of ancient times.' *Papers of the Paint and Varnish Society*, London, 1911, p. 93; 'Minoan lime plaster and fresco painting.' *Journal of the Royal Society of British Architects*, London, 1911; 'The materials and methods of decorative painting.' *Royal Society of Arts, Cantor Lectures*, London, 1912; 'The mural paintings of Knossos.' *Papers of the Society of Mural Decorators and Painters in Tempera*, Vol. II. London, 1925. (See number 39.)

22. *On the nature and method of execution of specimens of painted plaster from the palace of Tiryns*—Noël Heaton. N.d., n.p.

23. *The materials of the painter's craft in Europe from the earliest times to the XVIIth century with some account of their preparation and use*—A. P. Laurie.

Edinburgh, T. N. Foulis, 1910. An illustrated study of ancient painting materials and methods, with an extensive bibliography.

24. *The pigments and mediums of the old masters*—A. P. Laurie. Macmillan & Co., Ltd., 1914. Studies of old techniques based on chemical and microscopic examinations as well as upon a study of early records. Microscopy of brushwork and microchemical examination described.

25. *On the chemistry of the ancient Assyrians*—R. Campbell Thompson. Luzac and Company, 1925. Contains many references to pigments.

26. *Ancient Egyptian materials and industries*. 2nd Edition—A. Lucas. E. Arnold and Company, 1934. A carefully authenticated study of Egyptian technology, including the materials and methods used in the arts.

27. *Origins and development of applied chemistry*—J. R. Partington. Longmans, Green & Co., Ltd., 1935. Studies of pigments, other materials, and technical processes of the earliest civilizations; very complete and detailed references.

28. *The material of medieval painting*—Daniel V. Thompson, Allen and Unwin Ltd., 1936. Early methods and materials lucidly considered and explained.

PAINTING MATERIALS AND METHODS—MODERN

29. *Letters to a painter on the theory and practice of painting*—W. Ostwald. Translated by H. W. Morse. New York, Ginn and Company, 1907. One of the first books written by a modern chemist on the subject; contains much original and practical information on the principles of sound working methods.

30. *The chemistry of paints and painting*. 4th Edition—Arthur H. Church. Seely, Service and Company, 1915. For many years the outstanding artists' book on materials and methods. Although outmoded in part, it is still of considerable value and interest. The author was the leading English authority of the nineteenth and early twentieth centuries.

31. *Materials for permanent painting* (1911) and

32. *How to paint permanent pictures* (1922)—Maximilian Toch. New York, Van Nostrand. Instructions to artists on correct technique for oil painting, by an American authority.

33. *Entwickelung und Werkstoffe der Wandmalerei*—Dr. Alexander Eibner. Munich, Heller, 1926. A study of mural methods and materials of all ages. Extensive bibliography.

34. *The painter's methods and materials*—A. P. Laurie. Seeley, Service & Co., Ltd., 1926. Covers most of the essential points on oil, tempera, and fresco painting in a satisfactory manner.

35. *Simple rules for painting in oils*—A. P. Laurie. London, Winsor and Newton Ltd., 1932. Concise short book of outlined rules for art students.

36. *The permanent palette*—Martin J. Fischer. Mountain Lake Park, Maryland, National Publishing Society, 1930. Some data and personal recommendations on materials and methods for permanent painting, clearly presented

37. *Notes on the techniques of painting*—Hilaire Hiler. Faber & Faber Ltd., 4th edition, 1948. Contains practical hints and personal observations on artists' materials and procedures, also a large polyglot bibliography. Includes many compiled recipes and instructions, mostly of French origin.

38. *The materials of the artist and their use in painting, with notes on the techniques of the old masters*—Max Doerner. Harrap & Co., Ltd. Covers the various techniques of painting from all angles of interest to the artist. The translation does

not have quite the clarity and directness of the original, and the contents have not been adapted to American or English usage. Doerner's analyses of the techniques of the old masters are very well done, and are based upon a study of old pictures, documentary evidence, and reconstructive methods.

39. *Papers of the Society of Mural Decorators and Painters in Tempera.* Vol. I—Edited by M. Sargant-Florence, 1924; Vol. II—Edited by John D. Baxter, 1935; Vol. III—Edited by M. Sargant-Florence, Dolphin press, 1936. Studies, papers, and reports by members of the Society on the methods and materials of painting.

TEMPERA

The general work on painters' methods and materials listed in the preceding section include references to tempera painting.

40. *Tempera und Tempera Technik*—Ernst Friedlein. Munich, Callwey, 1906. One of the first modern practical handbooks on the subject. Contains a collection of its author's own recipes for a large number of grounds and emulsions. Although many of these are outmoded or contrary to best practice, as will be realized by experienced painters, the book contains much of interest.

41. *The practice of tempera painting*—Daniel V. Thompson, Oxford University Press, 1936. A book of instruction on tempera painting, based upon and derived from the method of Cennini and adapted to modern usage.

42. *Papers of the Society of Mural Decorators and Painters in Tempera.* See number 39.

WATER COLOUR

43. *The art of landscape painting in water colours*—Thomas Rowbotham. Winsor and Newton.

44. *A system of water-colour painting*—Aaron Penley. Winsor and Newton.

45. *A guide to water-colour painting*—R. P. Noble. George Rowney and Company.

The above three small handbooks, first published in the nineteenth century and continued in many reprinted editions, are practical guides to the older type of craftsmanship.

46. *Making water colour behave* (1932) and

47. *Making the brush behave* (1935)—Eliot O'Hara. Putnam & Co., Ltd. These two books, ostensibly written for the novice, contain much of interest to professional painters. Manipulations are explained according to the writer's personal methods. Modern, direct methods are emphasized.

PASTEL

48. *A manual on pastel painting*—L. A. Doust. Frederick Warne and Company, Ltd., 1933. Instruction on technique; studies of the various effects which can be produced by pastel.

49. *The art of pastel*—Terrick Williams. Pitman & Sons Ltd., 1937. Instructions and hints on techniques.

GRAPHIC ARTS

The first three are some of the earliest treatises on lithography:

50. *A complete course in lithography*—A. Senefelder. London, 1819. The original work of the inventor of the process.

51. *The art of drawing on stone*—C. Hullmandel. London, 1824.

52. *A manual of lithography*—A. Raucourt. London, 1832.

53. *The grammar of lithography*—W. D. Richmond. Several editions through the nineteenth century. This English manual is a complete work on the subject but is of minor interest to the artist because it is largely concerned with industrial methods. The more modern industrial books on the subject are still further removed from the artist's viewpoint.

54. *American graphic art*—Frank Weitenkampf. Macmillan & Co., Ltd. A history and critical review of all artistic, reproductive, illustrative, journalistic, and industrial graphic-arts media in the United States. Illustrated. Bibliography.

55. *The art of etching*—E. S. Lumsden. Seeley Service & Co., Ltd., 1925. Complete and detailed English manual of practical etching; illustrated. Includes variations such as dry point and aquatint.

56. *Lithography for artists*—Bolton Brown. Chicago, 1929. An outline of artistic lithography for the artist who prints his own stones and makes his own crayons, inks, etc., based on the author's personal opinions and preferences.

57. *Lithography as a fine art*—A. S. Hartrick. Oxford University Press, 1932. A practical handbook.

58. *Making an etching*—Levon West. The Studio Ltd., 1932. An elementary outline of the process; illustrated with 17 action photographs, and reproductions of typical works of 16 artists.

59. *Handbook of print making and print makers*—John Taylor Arms. New York, Macmillan, 1934. Brief, concise outlines of the graphic-arts techniques, and a rather complete outline of the history of each. Critical estimates of the artists of the past and present.

60. *Silk screen practice and the roller process*—F. A. Baker. Blandford Press, 1934. Almost entirely concerned with industrial practice.

61. 'Lithography'—Article in *Encyclopaedia Britannica*, 14th Edition. The section headed 'The Process' was written by George C. Miller, an American printer of artists' lithographs, and gives a concise description of modern methods.

62. *Aquatint*—B. F. Morrow. Putnam & Co., Ltd., 1935. Describes the technique of aquatint and all its variations, with reproductions of contemporary American work.

63. *Making a lithograph*—Stow Wengenroth. The Studio Ltd., 1936. An elementary description of lithography for beginners with 15 action photographs of the various processes, and reproductions of typical examples of the techniques of 16 artists.

64. *The silk screen printing process*—Jacob S. Biegeleisen and E. J. Busenbark. McGraw-Hill Publishing Co., 1938. Covers the industrial applications of silk screen, with some reference to its use by artists.

Colour Printing: a practical demonstration of Colour Printing by Letterpress, Photo-offset lithography, and Drawn lithography, with illustrations demonstrating alternative methods of production and including a comprehensive colour chart—Thomas E. Griffits. Faber & Faber Ltd., 1948.

The Technique of Colour Printing by Lithography: a concise manual of drawn lithography—Thomas E. Griffits. Faber & Faber Ltd, 3rd edition., 1948.

A Handbook of Printing Types with Notes on the Style of Composition and Graphic Processes used by Cowells—John N. C. Lewis. Faber & Faber Ltd., 2nd edition, 1948.

Wood Engraving—R. John Beedham. With an Introduction by Eric Gill. Faber & Faber Ltd., 7th impression, 1948.

William Blake's Engravings edited with an Introduction by Geoffrey Keynes. Faber & Faber Ltd., 1950. With 142 illustrations (25 of these printed from electrotypes of Blake's original engravings). Contains descriptions of Blake's own methods of engraving and etching.

Processes of Graphic Reproduction in Printing—Harold Curwen. Faber & Faber Ltd., 2nd edition, 1949. A comprehensive survey of every method. With 18 insets, some in colour, and 135 line drawings.

Chemistry and Technology of Painting Materials

The books on the technology of paints, varnishes, pigments, and their raw materials are written mostly from the viewpoint of large-scale industrial production, and although they are of value for study and reference, the information they contain is only occasionally directly applicable to artists' practice.

The procedure for gathering chemical or technical references from periodicals is familiar to those who are equipped to assimilate such information. Scientific, technical, and trade journals are systematically indexed and are also brought together periodically in such indexes as *Chemical Abstracts*, *Industrial Arts Index*, etc., and in the catalogues of libraries.

Besides the general chemical journals, the following periodicals may be mentioned as having particular interest for those concerned with the subjects mentioned above: *Journal of the Oil and Colour Chemists Association. Journal of Chemical Education, Paint and Varnish Production Manager, Technical Studies in the Field of the Fine Arts*, and some of the trade journals which serve the various industries.

General

65. *Chemistry and technology of paints*—Maximilian Toch. Third Edition. New York, Van Nostrand, 1925. A standard American work for paint manufacturers and chemists.

66. *Outlines of paint technology*—Noël Heaton. Charles Griffin & Co., Ltd., 1928. A standard review of industrial practice.

67. *The chemistry of paints, pigments, and varnishes*—J. Gauld Bearn. Ernest Benn, Ltd., 1933. A concise outline of industrial methods.

Pigments

68. *Colours for painting*—Riffault, Vergnaud, and Toussaint. Translated from the French by A. A. Fesquet. Philidelphia, Henry Carey Baird, 1874. A complete and authentic contemporary account of early and middle nineteenth-century methods.

69. *A treatise on colour manufacture*—Georg Zerr and R. Rubencamp. Charles Griffin and Co., Ltd., 1908. An English translation of a German work, complete and accurate; and a more recent German edition, Berlin, Union, 1922.

70. *Artists' pigments*—Frederick W. Weber. New York, Van Nostrand, 1923. A catalogue and description of pigment colours, with a considerable section on elementary theoretical chemistry as it concerns the manufacture and reactions of pigments.

71. *The manufacture of lakes and precipitated pigments*—A. W. C. Harrison. Leonard Hill, Ltd., 1930. A concise outline; covers all aspects and applications of pigments. Bibliographies and reviews of researches.

72. The German *Farbentabellen von Gustav Schultz* and the

73. British *Colour index of the Society of Dyers and Colourists* are authoritative catalogues of all dyestuffs, and include sections on paint pigments. They are standard reference books for colour chemists.

Drying Oils

74. *Über fette Öle, Leinölersatzmittel und Ölfarben*—Alexander Eibner. Munich, B. Heller, 1922. An important work on drying oils with particular reference to artists' paints; original work and studies of older researches.

75. *Drying oils and driers*—London, Oil and Colour Trades Journal, 1924. Concise, elementary outline of the chemistry of drying oils.

76. *Vegetable fats and oils*—Louis Edgar Andés (translated from the German). 4th edition revised and enlarged by H. B. Stocks. Scott and Greenwood and Son, 1925. One of the older reference books, revised for modern use.

77. *The chemistry of drying oils*—R. S. Morrell and H. R. Wood. (Oil and Colour Chemistry Monographs.) Ernest Benn Ltd. A standard work on drying oils; includes references to important researches.

78. *The chemical technology of oils, fats, and waxes.* 3 Vols.—J. Lewkowitsch. Macmillan & Co., Ltd., 1922–38. A complete, authoritative treatise.

Varnishes

79. *Varnishes and their components*—R. S. Morrell. Oxford University Press.

80. *Varnish making*—T. Hedley Barry and George William Dunster. Leonard Hill, Ltd., 1934.

Resins

81. *Natural varnish resins*—T. Hedley Barry. Ernest Benn, Ltd., 1932. A complete study of varnish resins.

82. *Die Harze*—Alexander Tschirsch and E. Stock. Berlin, Borntraeger, 1933–1935. An exhaustive treatise on all resins.

Asphalts

83. *Blacks and pitches*—H. M. Laughton. New York, Van Nostrand, 1925.

84. *Asphalts and allied substances.* 4th Edition—H. Abraham. Chapman & Hall Ltd.

Lacquers and Synthetic Resins

85. *Pyroxylin enamels and lacquers.* 2nd Edition—Samuel P. Wilson. Constable & Co., Ltd.

86. *The chemistry of synthetic surface coatings*—William Krumbhaar. Chapman & Hall Ltd.

86a. *Synthetic resins and allied plastics*—R. S. Morrell; collaborators: T. Hedley Barry, R. P. L. Britton, H. M. Laughton. Oxford University Press, 1937.

Solvents

87. *Volatile solvents and thinners*—Noël Heaton. Ernest Benn Ltd., 1926.

88. *Solvents*—Thomas H. Durrans. Chapman and Hall Ltd., 1938.

RECIPES

89. *The Scientific American cyclopedia of formulas*—Albert A. Hopkins, editor. New York, Scientific American Publishing Company, 1935.

90. *20th century book of formulas, processes, and trade secrets*—Gardner D. Hiscox, editor. Crosby Lockwood & Son, Ltd., 1937.

91. *The chemical formulary*. 3 Vols.—H. Bennett, editor. New York, Van Nostrand, 1933–36.

CHEMICAL HANDBOOKS

92. *Handbook of chemistry*—Norbert A. Lange. Sandusky, Ohio, Handbook Publishing Company.

93. *Handbook of chemistry and physics*, edited by C. D. Hodgman. Cleveland, Chemical Rubber Company.

93a. *Chemical annual*, edited by John C. Olsen. Chapman & Hall Ltd.

Tables, factors, and concise reference data for chemists. These books are usually revised annually.

TESTING AND ANALYSIS

94. *Physical and chemical examination of paints, varnishes, lacquers, and colours*—Henry A. Gardner. Washington, Institute of Paint and Varnish Research. Revised annually. The most complete volume on the subject; known as the 'paint chemists' Bible'.

CONSERVATION, TECHNICAL STUDIES, RESEARCH, ETC.

95. *The cult of old masters and the Romney case*—Rickard W. Lloyd. Skeffington & Son, Ltd., 1918. The story of litigations on the authenticity of old masters.

96. *The cleaning and restoration of museum exhibits*—Alexander Scott. H.M. Stationery Office, three reports, 1921–23–26. Modern methods of conserving and restoring all types of museum exhibits. Also see a more recent addition in *Museums Journal*, Vol. 33 pp. 4–8, April 1933.

97. *The gentle art of faking*—Riccardo Nobili. Seeley Service & Co., Ltd. An interesting essay on the counterfeiting of works of art from the earliest times to the present.

97a. *Fakes: a Handbook for Collectors and Students*—Otto Kurz. Faber & Faber Ltd., 1948. Deals with artistic forgeries—faked pictures, drawings and sculpture. 95 illustrations showing originals and fakes.

98. *The restoration of bronzes and other alloys*—C. G. Fink and C. H. Eldridge. New York, Metropolitan Museum, 1925. (Also see *Encyclopaedia Britannica*, 14th Edition, article 'Bronze and Brass Ornamental Work', section 'Corrosion and Restoration'.) A description of the restoration of corroded antique bronzes and other metals by an electrolytic method which converts the corrosion back into its metallic form, thereby retaining the surface markings of the original work.

99. *Pictures and how to clean them*—T. R. Beaufort. John Lane, The Bodley Head Ltd., 1926. Deals mainly with the conservation and repair of pictures on paper.

100. *The scientific examination of pictures*—Martin A. De Wild. Translated from the Dutch. G. Bell & Sons, Ltd., 1929. Original researches on the applications

of modern techniques to the study of painting methods and materials, the conservation of paintings, etc.

101. *A study of Rembrandt and the paintings of his school by means of magnified photographs*—A. P. Laurie. E. Walker, Ltd., 1930.

102. *Paint, paintings, and restoration*—Maximilian Toch. New York, Van Nostrand, 1931. An account of modern advances in the technology of pigments, solvents, identification of old paintings, and techniques of conservation.

103. *The brushwork of Rembrandt and his school*, illustrated by photomicrographs—A. P. Laurie. Oxford University Press, 1932.

104. *Antiques, their restoration and preservation*—A. Lucas. Revised edition. Edward Arnold & Company Ltd., 1932. Conservation of miscellaneous museum exhibits: a complete guide to the subject.

105. *Infra-red photography*—S. O. Rawling. Blackie and Son, Ltd., 1933.

106. *The preservation of antiquities*—H. J. Plenderleith. The Museums Association, 1934. Conservation of miscellaneous museum collections. See number 108.

107. *New light on old masters*—A. P. Laurie. Sheldon Press, 1935. A general account of methods, materials, and technical studies of painting, in a rather popular version.

108. *The conservation of prints and drawings*—H. J. Plenderleith. The Museums Association, 1937. A sequel to number 106. Both of these small books are compilations and reviews of the most modern and approved methods as standardized and practised by their author at the British Museum. Written with regard for the requirements of the non-professional restorer.

109. *Stop that smoke!*—Henry Obermeyer. New York, Harpers, 1933. A popularized account of air pollution in America, with bibliography and sources of data on many aspects of the subject.

110. *Technical studies in the field of the fine arts*. Cambridge, Fogg Museum, Harvard University. A quarterly journal, published since 1932. It prints original papers on materials and methods of art, both by the staff and by outside contributors, and abstracts of all the important current publications in this field throughout the world. The only American periodical in its field.

NOTE. The following books, previously listed under other headings, also treat these topics:

10. Mérimée (1839)
24. Laurie (1914)
30. Church (1915)
34. Laurie (1926)
58. Doerner (1934)

SCULPTURE

111. *Modelling and sculpture*—Albert Toft. Seeley Service & Co., Ltd. A beginner's manual of materials, tools, and methods of procedure for modelling, carving, casting, and bronzing. Reproductions of sculpture of all ages critically analysed.

112. *Modelling and sculpture in the making*—Sargeant Jagger. The Studio Ltd. ('How to Make It' series). A short, elementary outline; photographic illustrations.

113. *Trade names and descriptions of stones*—Frank A. Lent. New York, Stone Publishing Company (the magazine *Stone*), 1925. A descriptive list of all the American commercial varieties of building stones and the important European stones.

114. *The technique of early Greek sculpture*—Stanley Casson. Clarendon Press, 1933. Complete study of Greek methods of stone carving.

115. *Stone and marble carving*—Alec Miller. Alec Tiranti, Ltd., 1948. With a chapter on the pointing method by Professor Garbe, and a useful descriptive list of British carving stones.

Italian Renaissance methods are described in *Vasari on technique* (number 8).

PERSPECTIVE

116. *Perspective as applied to pictures*—Rex Vicat Cole. Seeley Service & Co., Ltd. A thorough and complete English textbook for artists.

117. *Elementary Freehand perspective*—Dora M. Norton. John Lane, The Bodley Head Ltd., 1928. A short study in non-mathematical perspective for beginners.

118. *A manual on simple perspective*—L. A. Doust. Warne & Co., Ltd. 1935. A short study in non-mathematical perspective for beginners.

119. *Perspective*—Frank Medworth. Chapman & Hall Ltd., 1937. Perspective applied to pictures from a careful, accurate viewpoint, dealt with in an advanced manner.

CHINESE AND JAPANESE MATERIALS AND TECHNIQUES

On Japanese pigments—T. Takamatsu. Tokyo, 1878. Researches on the nature of Japanese pigments. The total list resembles those in the seventeenth- and eighteenth-century English manuals, where all sorts of permanent and fugitive colours are named without discrimination; the vegetable pigments, for the most part, are very similar in nature to those in European use in the seventeenth and eighteenth centuries.

The pictorial arts of Japan—William Anderson. Sampson Low, 1886. A complete, illustrated study of art, artists, techniques, and works of art.

On the laws of Japanese painting—Henry P. Bowie. San Francisco, Paul Elder, 1911. An exposition of Japanese theories, principles, and techniques by an American who was trained in the Japanese school of painting.

'Studies on the ancient pigments in Japan'—Rokuro Uyemura. *Eastern Art*, Vol. III. Philadelphia, 1931.

'Linear perspective in Chinese paintings'—Benjamin March. *Ibid.*

Some technical terms of Chinese painting—Benjamin March. Kegan Paul Ltd., 1935. A study of Chinese artists' terms, techniques, materials, etc.

Perspective in early Chinese painting—Wilfrid H. Wells. E. Goldston, 1935. Analyses and theories of Oriental rules of perspective.

COLOUR

The following works present various systems of colour standardization and nomenclature. Their numerical designations and terms for hues, shades, tones, etc., are used to a limited extent by writers for accurate identifications of specific colours.

Colour standards and colour nomenclature—Robert Ridgway. Washington, 1912.

Atlas of the Munsell colour system and a colour notation. New York, 1919.

The Munsell book of colour—A. H. Munsell. Baltimore, Munsell Colour Company, 1929.

A dictionary of colour—A. J. Maerz and M. R. Paul. McGraw-Hill Publishing Co., Ltd., 1930.

Colour science—Wilhelm Ostwald. Translated from the German by J. Scott Taylor. Vol. 1, *Colour theory and colour standardization*; Vol. 2, *Colour measurements and colour harmony*. Winsor and Newton, 1933.

The Ostwald colour album—Wilhelm Ostwald. Winsor and Newton, 1933. Companion to the above.

The following books deal with systems of colour arrangement and control as applied to the artist's palette and picture:

A step-ladder to painting—Jan Gordon. Faber & Faber Ltd., 8th edition, 1950. With 67 illustrations.

The painter's pocket-book of methods and materials—Hilaire Hiler. Faber & Faber Ltd., 7th edition, 1950. Contains a large amount of information in small bulk; a comparative survey of all the most practical methods and materials of painting.

The practice of painting—F. Schmid. Faber & Faber Ltd., 1948. Traces the history of drawing and painting in some of the major European Schools from a practical point of view. Describes the most important treatises on art and shows palette arrangements of famous painters. With many illustrations from engravings and paintings.

The painter's palette and how to master it—Bolton Brown. New York, Baker and Taylor, 1913.

The painter's palette—Denman Ross. Boston and New York, Houghton, Mifflin, 1919.

Colour-control: the Organization and Control of the Artist's Palette—Frank Morley Fletcher. Faber and Faber Ltd., 1936.

Suggestions for the study of colour—H. Barrett Carpenter, B. T. Batsford, 1923.

A working system of colour—Frederick Leroy Sargent. New York, Henry Holt, 1927.

Modern colour—C. G. Cutler and S. G. Pepper. Cambridge, Harvard University Press, 1933.

Colour harmony, its theory and practice—Arthur B. Allen. Warne and Co., Ltd., 1937.

Lettering

The study of lettering is of greatest concern to those engaged directly in the designing of books, posters, inscriptions, advertisements, etc. From the viewpoint of the general practice of art, the subject is of more occasional interest; in fact, the average artist who has not made a thorough study of the subject is quite often apt to have a very poor command of correct principles when occasion for the use of lettering arises.

The study may be approached from two distinct viewpoints—from that of the student of paleography and from that of the craftsman with the aim of practical application. A knowledge of the history and origin of the various basic letter forms is, of course, a necessary adjunct to a complete training in lettering design, and some understanding of it is necessary to avoid errors in construction; but the average designer of letters is more interested in the practical aspects of the subject. The following books are a few selections from a field in which a great number and variety of manuals are available:

Lettering—Thomas W. Stevens. New York, Prang Publishing Company, 1926. A standard textbook.

Lettering for students and craftsmen—Graily Hewitt. Seeley Service & Co., Ltd. An English manual of classic lettering.

Writing and illuminating and lettering—Edward Johnston. 15th edition. Pitman & Sons, Ltd., 1927. A complete manual of classical professional lettering, includes architectural inscriptions.

The alphabet—Frederick W. Goudy. New York, Mitchell Kennerly, 1922. Typographical alphabets.

The design of lettering—Egon Weiss. New York, Pencil Points Press, 1932. Principally concerned with architectural inscriptions.

A book of scripts—Alfred Fairbank. Penguin Books, 1949.

Anatomy and Figure Drawing

Living anatomy: A Photographic Atlas of Muscles in Action and Surface Contours—R. D. Lockhart, M.D., Ch.M. Faber & Faber Ltd., 2nd edition, 1950. With 154 illustrations.

Anatomical diagrams for the use of art students—James M. Dunlop, with an introduction by John Cleland, Bell & Sons, Ltd. Employs a clear and practical method of instruction.

Constructive anatomy—George B. Bridgman. John Lane, The Bodley Head, 1925. A popular book on anatomy as applied to artistic figure drawing. The following three titles are by the same author:

Bridgman's life drawing. 1926.

The book of a hundred hands. 1926.

Heads, features, faces. 1932.

Figure drawing—Frank Medworth. Faber & Faber Ltd., 3rd edition, 1948. Anatomy and physiology take up about a third of the book: the rest is given to methods in drawing. With 101 pages of 288 drawings.

The human figure—John H. Vanderpoel. Batsford Ltd., 1935. Anatomy applied to figure drawing.

Human anatomy for art students—Sir Alfred Fripp and Ralph Thompson. Seeley Service & Co., Ltd. A complete English textbook on anatomy and figure drawing.

Animal drawing—Frank Medworth. Faber & Faber Ltd., 3rd edition, 1948. Contains a few hundred drawings of the many aspects of animal and bird forms, with notes on typical attitudes and their causes.

The horse: its action and anatomy by an artist—Lowes D. Luard. Faber & Faber Ltd., 1935. Profusely illustrated with diagrams, drawings, photographs and anatomical plates in colour.

Animal painting and anatomy—W. Frank Calderon. Seeley Service & Co., Ltd., 1936. A complete and well-illustrated English work.

Technique of Painting

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